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M.Sc. Thesis in International Studies in Aquatic Tropical Ecology

Community-level analysis of anthropogenic impacts on rocky shore communities in Sri Lanka

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I herewith confirm that I have elaborated my diploma thesis titled

Community-level analysis of anthropogenic impacts on rocky shore communities in Sri Lanka

single-handed and without using other resources than mentioned therein.

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TO MY PARENTS

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ABSTRACT

Human activities threat seashore communities in many areas of the world and their impacts on coastal ecosystem are a matter of increasing concern. Present study describes the anthropogenic disturbances on the rocky shore community structure by comparing the benthic communities of disturbed and non-disturbed areas in Sri Lanka where rocky shores remain virtually untouched so far by experimental studies. Impacts of human disturbances; trampling, handling and exploitation on the community structure of rocky macro benthic assemblages were tested in high-, mid- and low-intertidal area by stratified sampling method at Rumassala marine sanctuary and adjacent two localities at either side of the marine sanctuary, Galle and Unawatuna. Univariate measures, log series model and multivariate techniques were used to discriminate the communities with respect to the disturbances. Proximity of study localities and indistinguishable physicochemical parameters of sea surface water (temperature, Salinity, conductivity, dissolved oxygen and pH) indicated that overall environment of the study area was relatively uniform and changes in community structure was due to human disturbances. Human disturbances documented as visitor censuses by transect walk method lead to categorize the Rumassala as non-disturbed, Unawatuna as disturbed with Galle being of moderately disturbance. Community abundance showed a decreasing trend along with increasing disturbances, albeit community biomass, due to opportunistic algae species, increased in parallel to disturbances. Computed Index of disturbance revealed that macrofauna was very sensitive to the disturbances and increased disturbances reduced their competitive pressure on macroalgae, leading to outstanding macroalgal growth. Macroalgal domination in disturbed communities contributed to lessen the heterotrophic dominance in Galle and Unawatuna. 96 macrobenthic taxa were encountered from the study and Species richness, Shannon and Fisher's diversity index showed decreasing trend with increasing disturbances. Moreover, initial rising slope of species accumulation curves for three communities indicated that community evenness was low in disturbed communities. The community compositions from dominant conservative species to fast growing opportunistic species were well described by the log series model, showing left skewed distribution. The SIMPER analysis further confirmed that most biomass dominant species in stress status were the opportunistic species such as *Valoniopsis pachynema, Gracilaria cassa* and *Padina boerggesenii*. Providing strong support to the results highlighted from univariate measures and log series model, multivariate cluster analysis and nMDS plots completely separated three communities at ordinal scale. This separation was further confirmed by one-way ANOSIM test with significantly higher (2.9%) similarity of study sites within each community. Present study indicated that, allowing less time for recovery, human activities created press-type disturbance on macro-benthic assemblages, and subsequent changes in community structure could be attributed to less suitable substrata. Study proposed that ecological stress is the best measured by multiple methods, and results from different approaches provide the robustness necessary to judge the reliability of the conclusion. Present study strongly supports the growing concern that human activities impact on intertidal assemblages all over the world by changing community composition. Present finding is a contribution to the published literature that is scarcer from tropical rocky shores.

ABBREVIATIONS

AFDW	Ash Free Dry Weight
ANOSIM	Analysis of Similarity randomization test
ANOVA	Analysis of Variance
AW	Ash Weight
AWI	Alfred Wegener Institute for Polar and Marine Research
CA	Cluster Analysis
DFAR	Department of Fisheries and Aquatic Resources
DO	Dissolved Oxygen
DW	Dry Weight
DWC	Department of Wildlife Conservation
FARA	Fisheries and Aquatic Resources Act
FFPO	Fauna and Flora Protection Ordinance
FMAs	Fishery Management Areas
IDH	Intermediate Disturbance Hypothesis
IUCN	International Union for the Conservation of Nature
MDS	Multidimensional Scaling Ordination
MPAs	Marine Protected Areas
nMDS	Non-Metric Multidimensional Scaling Ordination
NARA	National Aquatic Resources Research Agency
PRIMER	Plymouth Routines of Multivariate Ecological Research
RMS	Rumassala Marine Sanctuary
SAC	Species Accumulation Curves
SAD	Species Abundance Distributions
SAM	Special Area Management project
SIMPER	Similarity Percentage
SPSS	Statistical Package for the Social Sciences
UN	United Nations
WW	Wet Weight
ZMT	Center for Tropical Marine Ecology

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INTRODUCTION

1.1 Rocky shores

Rocky shores, the most extensive littoral habitats on eroding wave exposed coasts throughout the coastlines of the world's oceans, are ecologically very important. This natural habitat is further increased by the plethora of artificial hard structures such as breakwaters, jetties, docks, groynes, dykes and seawalls which essentially function as artificial rocky shores (Crowe et al., 2000). Rocky shores are variable coastal habitats and they, depending on local geology, may range from steep, overhanging cliffs to wide, gently shelving platforms, from smooth uniform slopes to highly dissected irregular masses or even extensive boulder beaches. Therefore, rocky shores are rarely smooth slabs of rocks, but instead crossed with cracks, crevices, gullies and pools which provide special habitats with their own set of advantages and problems (Raffaelli & Hawkings, 1999). Most notably, rocky intertidal shores encompass a gradient of environmental conditions from fully marine bellow low tidal levels to fully terrestrial where splash and spray reach to the highest level above high tide (Underwood, 2000). Being a heterogeneous environment, intertidal rocky coastlines provide a multiple range of habitats that support a great variety of living forms (Terlizzi et al, 2002; Menge et al, 1986). Differences in physical and biological processes are the main cause of variation in intertidal communities, both in time and space (Paine & Levin, 1981; Sousa, 1984). Physical processes can include disturbances such as wave action, temperature, irradiance or salinity, whilst biological processes may include settlement, recruitment, predation and competition (Terlizzi et al., 2002).

Rocky shore organisms must be tolerant to a wide range of natural conditions. Shore plants and animals have evolved a variety of morphological, physiological and in case of animals' behavioral mechanisms to withstand the rigors of the shore, particularly aerial exposure and wave action. In many cases, animals opt to cope with environmental changes by behavioral rather than physiological mechanisms, although some do both (Raffaelli & Hawkings, 1999). Disturbance of the community by physical and biological factors may reduce the number of organisms in the community to the point at which there is less competition for resources, and hence less competitive exclusion and greater species diversity (Dethier, 1984). Therefore, rocky shores bear a large number of species of flora and fauna and they are especially rich in invertebrate fauna belonging to almost all invertebrate phyla. Apart from its widely recognized socioeconomic and ecological importance in marine coastal ecosystems, the rocky intertidal zone serves as a "natural laboratory" for elucidating the role of physical, biological and human factors in determining the abundance and distribution of organisms in nature (Tomanek & Helmuth, 2002).

1.2 Anthropogenic disturbances

Most of the threats to biodiversity in coastal zone are the demographic trends of increased human population densities in coastal areas (Gray, 1997). Intertidal zones are extraordinarily important both for people and wildlife. The natural productivity of the zone provides food, not only for humans, but also for important wildlife populations including marine species and migrating birds. Furthermore, intertidal regions form part of many landscapes that appeal to visitors, allowing the formation of important recreational and tourist economics (Bowers, 1999). These attract humans towards the intertidal area and provoke disturbance of its habitats, intensive exploitation and usage of its resources, thus creating an extraordinary pressure on the existing communities. Due to fact that many rocky intertidal communities, globally and locally, are subjected to a variety of stresses caused by human activities such as exploitation, trampling, research, educational field trips, seaside strolling, overturning rocks, photographing and fishing (Addessi, 1994; Liddle, 1975; Beauchamp & Gowing, 1982; Moreno et al, 1984 and 1986; Castilla & Duran, 1985; Kingsford et al, 1991; Povey & Keough, 1991; Keough et al, 1993; Lasiak & Field, 1995). Though biological communities of rocky shores may have the capacity to withstand or rebound from impacts generated by natural disturbances, large increase in the level of human disturbances inevitably alter the pattern of natural variability at various scales of organization within the community. This is because anthropogenic stresses are superimposed on stresses caused by natural environmental factors (Raffaelli & Hawkins, 1996). Strong linkages often exist among species (Paine, 1980) and therefore, rocky shore communities are sensitive to human induced disturbances that may play an important role in the shaping of species diversity through indirect influences on species abundances (Addessi, 1994; Brosnan & Crumrine, 1994; Keough & Quinn, 1998; Brown & Taylor, 1999; Milazzo, et al., 2004). Through the years, humans have substantially affected intertidal zones across the globe and this scenario has been proven by human exclusion experiments in rocky shore communities (Castilla & Duran, 1985; Castilla & Bustamante, 1989; Hockey, 1994), although this approach is difficult to implement in most places.

1.3 Marine protected areas as protective measures

Concerning ever-increasing pressure created by human activities, marine ecosystem management has developed over the past 30 years as an approach for comprehensively managing marine resources. In reality, marine ecosystem management does not manage natural resources, but the human interactions with these resources (Mangel, 2000; Larkin, 1996). As a tool for comprehensively managing human activities in areas of the ocean, implementing marine reserves or marine protected areas (MPAs) are the general strategy adopted (McNeely, 1994; Mangel, 2000; Dayton et al., 2000; Hooker et al., 2002) and the International Union for the Conservation of Nature (IUCN) has been heavily involved in the process (Salm & Clark, 1984). The World Conservation Union (IUCN) defined an MPAs as being “any area of inter-tidal or sub-tidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment” (Kelleher & Kenchington, 1992). The definition is broad and includes many coastal ecosystems, such as estuaries, lagoons, salt marshes, mangrove, and beaches as well as true marine ecosystems and oceanic waters. MPAs vary from large fishery reserves and multiple-use Park to small, strict conservation zones and sanctuaries depending on habitat, resource available for management and conservation objects (Perera & De Vos, 2007).

Marine protected areas can provide some obvious benefits, including conserving biodiversity and provision of important research sites for continued studies. Most notably, well managed MPAs can lead to significant improvement in habitat structure (Ashworth & Ormond, 2005; Gell & Roberts, 2003) and increase living forms both inside and outside park boundaries. Globally, therefore, marine protected areas are receiving increasing attention as management tools for protecting marine populations from human activities (Ticco, 1995). Exploited species generally attain a greater density, biomass and size inside the MPAs (Castilla & Duran, 1985; Oliva & Castilla, 1986; Hockery & Bosman, 1986; Godoy & Moreno, 1989; Keough et al., 1993), whereas the organisms on which they normally feed tend to be less abundant (Castilla & Duran, 1985; Moreno et al, 1986). Moreover, organisms that use exploited species as a food source, shelter or attachment also tend to be more abundant in MPAs (Lasiak & Field, 1995; Lasiak, 1999). But other species may be less abundant inside MPAs, because of reduction in availability of food and/ or an increase in competitive interaction with target species (Underwood, 1993).

Comparing site of high human use with such refuges from human disturbances is a globally accepted way in which the human impact on rocky communities can be assessed.

1.4 Assessment of anthropogenic stress

Anthropogenic stress is the response of biological entity (individual, population, community etc.) to an anthropogenic disturbance or stressor. Stress at one level of organization (e.g. individual, population) may also have an impact on other level, for example, causing alterations in community structure. However, it is sometimes difficult to detect the effects of anthropogenic stress at the level of individual organisms and impacts, therefore, are more often investigated at a population or community level (Crowe et al., 2000). Communities and community changes over time due to disturbances can be analyzed and characterized in different ways. One of the most common methods is by looking at community diversity which is a measure of complexity of the community (Laetz, 1998). Diversity consists of two components, the variety and relative abundance of species. Therefore, diversity measures take into accounts two factors; species richness, that is number of species, and evenness or equitability, that is how equally abundant the species are. Species diversity may thus be defined as a measure of species composition in terms of both the number of species and their relative abundances. Diversity indices characterize species composition at a given site and time. Providing a sound basis for the examination of species diversity, species abundance models describe the distribution of species abundance and give a better picture of the relationship between species richness and evenness. Several theoretical distributions such as geometric series of Motomura (1932), log series of Fisher et al, (1943), log normal of Preston (1948) and broken stick of MacArthur (1957) have been proposed to describe the abundances of species in communities. Of these models, log series and log normal distributions are most often being used in the field. In addition, it has been documented that the use of multivariate statistics is a much more precise way of detecting changes in benthic assemblages in space and time than the use of diversity indices (Gray, 2000). Multivariate analysis, in the form of dendrogram, multidimensional scaling (MDS) ordination, two-way nested analysis of similarity (ANOSIM) randomization test and the similarity percentage (SIMPER) based on abundance and biomass data would be helpful and are widely used to identify the differences, if any, among communities.

1.5 Experimental studies on rocky shores

One aspect of the past 30 years of intertidal ecology has been the rise of experimental manipulations as a crucial investigative tool (Underwood, 2000). The majority of intertidal research has been carried out on temperate communities, while quantitative and experimental studies in the topics have been confined to Central America, Hong Kong and Australia, which are all relatively distant from equator (Huang, et al., 2006; Hutchinson & Williams, 2001). Very few studies on rocky shores have been documented from tropical areas such as those published accounts of rocky shores in Galapagos Island, Malaysia and Singapore, representing lower latitude areas (Vinueza et al., 2006; Witman & Smith, 2003; Huang, et al., 2006). Experimental studies in rocky shores are needed from tropical areas, as the greatest levels of marine biodiversity are found in tropical countries which are developing (Gray, 1997). Being a tropical Island, Sri Lanka consists of several fragments of rocky shores along the coast, especially in the western margin of the country. However, these rocky shores remain virtually untouched so far by experimental studies.

1.6 Significance of coastal area, anthropogenic disturbances and MPAs in Sri Lanka

Sri Lanka (0 - 10º N Latitude, 80 - 82º E Longitude) is a tropical island, situated south of the Indian sub continent in the Indian Ocean and separated from it by the narrow Palk Strait. Aligned with the UN convention of the law of the sea, which was ratified by Sri Lanka in July 1994, the country enjoys a total extent of approximately 489 000 km^2 of maritime waters. The island, on the other hand, has a relatively small land area of 65 000 km^2 which gives a land to ocean area ratio of 1 to 7.5. The coastal zone is therefore of strategic significance to its populace due to accessibility to the vast resource base of the marine environment surrounding the island, in principle, from any point on the 1585km coast line (Hettiarachchi & Samarawickrama, 2005).

The Island's demographic trends towards the coastal habitats are similar with that of in rest of the world. Briefly, almost one third (32%) of the country's population, two thirds (65%) of the total urban population, two third (67%) of the industrial facilities and over 80% of the tourist infrastructure are accommodated only within one fourth (24%) of the Island's land area having a coastal boundary (CCD, 2000). Population density in the coastal region is projected to be 446 person/km^2 and along portions of the south coast is more than 1000 person/ km^2 (Olsen et al, 1992). Since 1983, economic sectors of manufacturing, construction, utilities, retail, trade, banking and land ownership have increased more in the coastal region than in the country as whole. The coastal region contributes about 40% of the nation's gross domestic product is indicative of increasing economic activity in the coastal area. As a consequence of these and other human impact on coastal ecosystems, intertidal habitats and communities in the Island are vulnerable to extraordinary pressure.

In order to manage and conserve the coastal zone in Sri Lanka, the coast conservation act enacted in 1981 covers the area within 300m landward of mean high water sea level and 2km seaward of mean low water. Marine areas came under the jurisdiction of many government departments: the Department of Wildlife Conservation (DWC) is responsible for marine sanctuaries, the National Aquatic Resources Agency (NARA) for marine research, the coast conservation department for coastal zone management and the Ministry of Fisheries and Aquatic Resources for fisheries. Currently, the major legislation used in declaring protected areas is the Fauna and Flora Protection Ordinance (FFPO) of 1993 which is administered by the DWC. Marine protected areas are being established through the special area management project (SAM) which is defined as a collaborative, adaptive and flexible approach to planning resource management within defined geographic area. It assumes that residents of a local community and local government have both the incentives and knowledge on the resources and resource-use problems to act collectively in ways that ensure that resources are used sustainably. These sanctuaries are open access for non-extractive uses and limited subsistence-based resource extraction under permit. In addition to this, there is a provision under the fisheries and aquatic resources act (FARA) of 1996, administered by the Department of Fisheries and Aquatic Resources (DFAR) to declare fishery management areas (FMAs) for the management of fisheries through the restriction of fishing effort by regulating access to a limited number of licensed operators (Perera & De Vos, 2007). Though there are arguments with stern management, such refuges declared as MPAs exist along the coast of Sri Lanka and can be used to illustrate how coastal ecosystems in the country are liable to anthropogenic disturbances. Table 1 summarizes the details of Sri Lankan MPAs that are already established and their selection criteria as MPAs or FMAs.

Table 1: Established Marine Protected Areas in Sri Lanka

Name	Year declared	Area (ha)	Responsible agency	Selection criteria
Hikkaduwa National Park	1979*	104	DWC	Biologically diverse and important marine habitat
Pigeon Island National Park	2003	471.4	DWC	As above
Bar Reef Marine Sanctuary	1992	30670	DWC	As above
Rumassala Marine Sanctuary	2003	1707	DWC	As above
Great and Little Basses FMA	2001	-	DFAR	Management of commercially important fishery resources
Polhena FMA	2001	-	DFAR	As above

* updated to the status of National park in 2002

1.7 Research objectives

The main objective of this study is to assess the impacts of anthropogenic disturbance on coastal communities in Sri Lanka using univariate, species abundance distribution and multivariate methods. The aim is to describe the anthropogenic impact on rocky intertidal macrobenthic communities by discriminating the community structure in human disturbed and non-disturbed protected areas.

1.7.1 Specific objectives

The general objective will be achieved through the following specific objectives, most of which adopt a comparative approach to the analysis of macrobenthic communities in protected and non protected areas. The specific objectives are;

- To compile the biodiversity of rocky intertidal macrobenthic assemblages in Rumassala marine sanctuary and adjacent areas
- To document human pressure on intertidal rocky shore communities in the study area

- To discriminate the disturbed and non-disturbed communities in order to check if community stress are proportional to the magnitude of disturbances

1.8 Research question

Do consequences of anthropogenic disturbances; trampling, handling and exploitation cause significant stress in intertidal rocky macrobenthic communities?

1.9 Hypothesis

Postulated hypothesis are;

- There are significant differences in macrobenthic community structures at human disturb and non-disturb rocky intertidal areas and resultant stress in the communities corresponds accordingly with magnitude of human disturbances.
- Magnitudes of anthropogenic disturbance on rocky macrobenthic communities are proportional to the number of people observed in the areas.

1.10 Methodological approach

Study is designed to conduct in rocky intertidal zone, comparing human disturbed and non-disturbed macrobenthic assemblages. In this regards, three study localities; one from Rumassala marine sanctuary and the other two from either side of the sanctuary were considered as three communities with different magnitude of human disturbances quantified as number of visitors per hour by transect walk method. Community stress, if any, discriminated by univariate, graphical species abundance distribution and multivariate methods can be related to the documented anthropogenic disturbances on intertidal macrobenthic assemblages from tropical Island, Sri Lanka.

MATERIALS AND METHODS

2.1 Study area

The study area lies within the wet zone of Southern Sri Lanka which is characterized by annual rainfalls of over 2000mm and an average annual temperature of about 27°C. The area is influenced by the south-west monsoon from May to October (IUCN Sri Lanka and the Central Environmental Authority, 2006). The tides are predominantly semi-diurnal with only marginal differences in the tidal constituents. Tidal range varies from 0.2m (during the neap period) to 0.8m (during the spring period) (Hettiarachchi & Samarawickrama, 2005) and, therefore, all study sites experienced continuous moderate to heavy wave action.

2.2 Study localities

Three sampling localities were selected the present study, namely Galle, Rumassala and Unawatuna. These three localities consist of continuous rocky shore with rocky boulders and dead coral bed. Rumassala lies in the marine protected area “Rumassala Marine Sanctuary” (RMS) and the other two localities, Galle and Unawatuna, on either side of the RMS. Of the three sampling localities, Rumassala is considered to be less or not disturbed by human activities. Conversely, the other two localities were considered as disturbed by human activities and Unawatuna, of the two disturbed localities, is the most disturbed sampling locality considering the number of persons observed in rocky intertidal area at the preliminary survey. A detailed description of each locality is summarized below. Figure 1 shows map of the study area and selected sampling localities.

2.2.1 Galle

Galle located 116km to the south of Colombo on the southwest corner of the island, is the capital city of Southern province in Sri Lanka. It is the best example of a fortified city built by Europeans in South and South-East Asia, showing the interaction between European architectural styles and South Asian traditions. The study locality in Galle bay area is situated to the northward from other two sites, Rumassala and Unawatuna. The area is popular among locals and majority of local visitors and some tourists visit the area for recreational activities including swimming, sea bathing, and snorkeling etc. If so, the area guarded the Sri Lanka NAVY camp and naval base harbor entrance and archeologically important Dutch fortress.

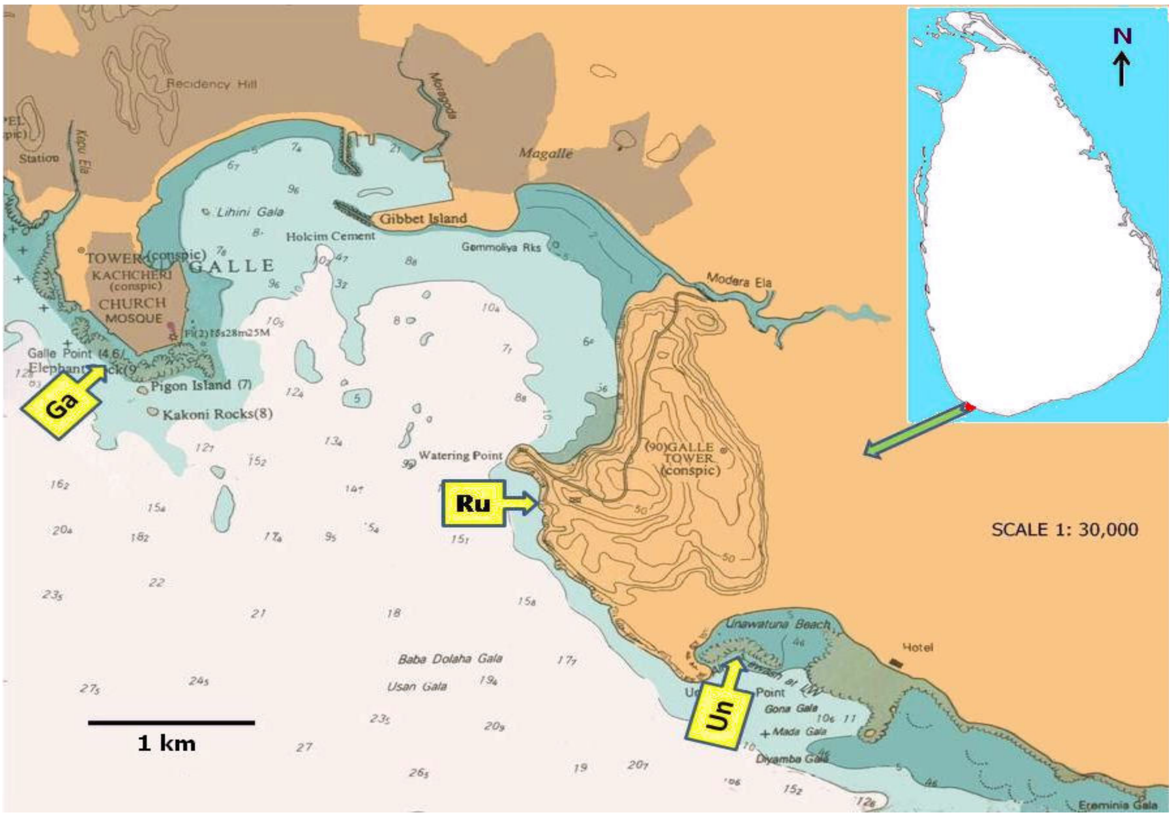

Figure 1: Detailed map of the study area showing three study localities (Ga- Galle, Ru- Rumassala, Un- Unawatuna).
Inset: Map of Sri Lanka showing the enlarged area

2.2.2 Rumassala

This study locality lies in Rumassala Marine sanctuary (6° 2’ 45N and 80° 13’ 45E to 6° 0 0 N and 80° 15’ 45 E), located in the southern end of Galle bay, in Galle district, Southern Sri Lanka. RMS encompasses a small near-shore coral reef named Bouna-Vista coral reef growing on hard substrate around the base of the Rumassala hill. RMS is different from other MPAs established in the country, due to its specific locality. That is, the rocky shore is surrounded by the hilly headland named Rumassala hill (average height 20m) with large number of endemic, endangered and medicinally (indigenous) important trees. The area has been declared as reserved forest (20 ha) that is managed by Department of Wildlife conservation. The hilly headland is steep towards the Bouna-Vista coral reef via intertidal rocky shore. Therefore, the shore area is referred to as “Jungle beach” in folklore, due to relative isolation of the site. Figure 2 shows the overview picture of part of the Marine sanctuary. In addition, as north ward end of the RMS area is near to the NAVY base harbor entrance, the area is declared as naval security zone. Therefore, human access is very limited to the intertidal area in RMS. Anyway, tourists from Galle and Unawatuna also visit the area for snorkeling and coral viewing and use the beach. SCUBA diving operators based on Unawatuna also conduct diving tours to the reef.

Figure 2: An overview picture of part of Rumassala Marine Sanctuary

2.2.3 Unawatuna

Unawatuna is the most southward one of the three study localities. The area is a renown tourist area and most of the tourist hotels are constructed near to the beach. Beach area in Unawatuna is a popular picnic and recreational area for tourists and locals than the Galle. The most SCUBA diving operators in study area are based on Unawatuna. The snorkeling, swimming, sea surface sliding and SCUBA diving is the most popular activities commonly found in this area among tourists as well as locals. Therefore, I presume this area as the anthropogenically most disturbed one.

2.3 Study period

The study visits were carried out from September, 2007 to February, 2008 with a month interval between the sample times. Depending on weather conditions and tidal variations, between 2 to 4 days were needed to survey one sampling locality (6 to 12 days for one sampling 0ccation at three localities).

2.4 Oceanographic conditions

In order to check concordance of the oceanographic conditions in study area, several physicochemical parameters of sea water; i.e. surface water temperature, salinity, dissolved oxygen (DO), conductivity and pH, were quantified twice a month at each study site during the study period (10 times). The values were taken using portable digital meters. That is, surface water temperature, Salinity, DO and Conductivity were quantified using YSI 85 Oxygen, Conductivity, Salinity and Temperature meter (Yellow Springs, Ohio, USA) and pH was measured using portable pH meter (Accumet AP 61).

2.5 Documentation of human factor

Major activities of the visitors observed at the preliminary study and considered as disturbed activities to rocky community were; trampling, snorkeling, SCUBA diving, sea surface sliding, coral viewing, collection of certain species, research, overturning rocks and photographing. All these activities were preliminary categorized into three main activities, i.e., trampling, exploitation and handling, for the present study and denotes as human disturbances hereafter. In order to document human disturbance to the intertidal rocky shore in each study localities, density of people doing disturbances of any of above category were counted following the transect walk method applied previously by Addessi, (1994) and Huang and others (2006). The time for each census was standardized to a walk of 25 minutes from one end to the other and similar return to start point. No of person presence in the intertidal zone were counted at each walk. For each sampling date, data for two directions of census walk was not pooled, because of the non independency. The highest count was retained because highest density of location was the desired value of interest. Human pressure was determined by calculating the mean number of visitors per hour in each sector along the beach. Documentation of human pressure was carried out twice a month during the study period (10 times). Weekends and public holidays were more frequently selected, because more people visit the shore on weekends and public holidays than week days, as detected by preliminary survey.

2.6 Study species

The study focused on benthic macro-invertebrate (>5mm) and macroalgae communities existing on littoral rocky shores. The study examined the differences in diversity, abundance and biomass of all macro-invertebrates and macroalgae between three study localities. All fauna and flora subjected to present work were identified to the lowest possible taxonomic level, usually species, with the help of following literature and taxonomic keys; Atapattu, (1972); De Silva, (2005) & (2006); Fernando, (2006); Jones & Morgan, (1994); Kirtisinghe, (1978); Fernando, (2005); Mallikarachchi, (2004). In addition, identification of macro-algae was confirmed by comparing the morphological characters and images found in worldwide algal database; algaebase available at www.algaebase.org

2.7 Sampling design

From each study locality, four sites, named A, B, C and D, were selected randomly. These sites were at least 100m apart from each other. At each site, rocky beaches are arbitrarily divided into three zones along the tidal gradient. The divisions were high-tidal zone, mid-tidal zone and low-tidal zone. These three zones range from the upper limit of splash of spray zone in high-tidal zone to 0.5m water depth at lower low-tidal zone, owing to steep profile of the shore. Stratified sampling method was applied to collect the quantitative data at each tidal level.

2.8 Sampling procedure

A quadrat frame (0.5x0.5m=0.25m^2) subdivided into 25 equal squares (5x5) was used for sampling biota. Fiberglass tape measures were used for positioning all quadrates. In short, transect tapes 18m in length were placed parallel to the water fringe. At each 3m intervals, quadrat was placed on landward side and seaward side one after one to the transect tape (3+3=6 quadrat) and abundance of macroalgae and colonial animals within each quadrat was quantified as percentage cover in the field while that of solitary animals was quantified as number of individuals. All benthic macroalgae and macro-invertebrates were scraped off with the aid of a metal scraper. Encrusted animals were detached from the substratum with the help of a chisel and hammer. Small boulders and stones in the quadrates were also turned for the collection of animals. All biota collected from quadrat area were placed in a pre-labeled polythene bag and tied down with rubber bands. Applying same procedure, six quadrate samples were taken from each tidal level and total 18 quadrate samples were obtained from each study site. Samples were frozen in an ice filled container, since freezing is recommended rather than chemical preservation for subsequent biomass measurements (Hatcher, 1997; Ricciardi & Bourget, 1998). Samples were transported to the laboratory and kept in a deep freezer overnight.

Next day, all samples were washed with tap water to remove adhering sand, fine gravel, silt, mud and extra material. Macro-flora and fauna were identified and separated into species and wet-weight (WW) of each alga species were measured using top loading balance (Mettler PE 3600, precision ± 0.001g). Wet-weight of mollusk and echinoderms was taken with their shells. The samples were placed in respective polythene bags and kept in deep freezer until completion the whole process.

When processing for dry weight (DW), algae and invertebrates in each bag were processed separately. Each algae species were placed in pre-labeled crucibles separately and weighted. Then, lidded crucibles were placed in an Oven at 40-45 °C until attaining constant weight (Bymers et al, 2005). Macrofauna with shells were cracked with the help of cutter and animal soft bodies were removed manually with the help of a forceps. Animals without shells and soft bodies recovered from the shells were placed in pre-labeled crucibles and lidded crucibles were desiccated in an Oven at 110 °C for 24 hours. Allowing desiccated crucibles to reach room temperature, shell free dry weights (SFDW) were measured. Ash-weight (AW) of the same fraction of algae and invertebrates were measured after incineration of in a Muffle furnace (Yamato FM-36) at 450 °C for 10 hours. Ash free dry weight was calculated by AFDW= DW-AW (Palmerini & Bianchi, 1994). Whole processes up to AFDW for all algae and invertebrates were completed within 2 to 10 days from the sampling date.

2.9 Conversion of abundance data

There were two types of abundance data; percentage covers for macroalgae or colonial animals and individual numbers for solitary animals. There were two methods to standardize these values, i.e., convert to present-absent data or convert to percent (%) abundance data. But present absent data does not reveal real numerical abundances and percent abundance does not exceed 100 at all. After compromising, percentage cover data of colonial animals or macroalgae for each sampling occasion were converted into individual number as follows. Briefly, mean individual number of solitary species (IA_{mean}) and mean percentage cover of colonial or macroalgae species (PC_{mean}) were computed for each study site.

$$IA_{mean} = \frac{IA_{total}}{No\ of\ samples}$$

$$IA_{total} = total\ count\ of\ individual\ abundance\ for\ all\ solitory\ species\ at\ the\ site$$

$$PC_{mean} = \frac{PC_{total}}{No\ of\ samples}$$

$$PC_{total} = total\ count\ of\ percentage\ cover\ for\ all\ colonial\ species\ at\ the\ site$$

Then, corresponding individual numbers for each colonial or macroalgae species were computed separately as follows;

$$IA_{sp(i)} = PC_{sp(i)} \times \frac{IA_{mean}}{PC_{mean}}$$

where,

$IA_{sp(i)} = Corresponding\ individual\ number\ of\ colonial\ or\ macroalgae\ species, i$

$PC_{sp(i)} = percentage\ cover\ of\ colonial\ or\ macroalgae\ species, i$

2.10 Data analysis

According to Warwick and Clarke (1991), the available statistical methods could be categorized broadly into three methods: univariate, graphical/ distributional and multivariate. This terminology is widely used in publications of benthic ecology.

2.10.1 Index of disturbance

This ratio is introduced as size ratio by Pearson and others (1982) and higher index value denotes the lower community stress. Index of disturbance: Biomass to Abundance ratios (Pearson et al, 1982) was computed for macro-fauna and macro-flora separately for three study communities.

2.10.2 Biomass comparison

Macro-fauna: macro-flora ratio, indicate of whether there is autotrophic or heterotrophic dominance was computed for each study sites as well as for the three communities.

2.10.3 Univariate diversity measures

In univariate methods, relative abundances of the different species at site or time are reduced to a single index.

2.10.3.1 Species richness indices

A simple measure of species diversity is the species number recorded S (Magurran, 1988). Margalef's diversity index, D_{Mg}, (Margalef, 1958) derived using some combinations of S (total number of species recorded) and N (total number of individuals summed over all S species) was used to calculate the species richness. The equation used as follows;

$$D_{MG} = \frac{(S-1)}{\ln N}$$

where; S = the number of species recorded

N = the total number of individuals summed over all S species

2.10.3.2 Indices based on proportional abundance of species

The most widely used measure of species diversity is the information theory indices. Shannon and Weiner independently derived functions, known as Shannon index of diversity (H') assuming that individuals are randomly sampled from an "indefinitely large" population, was used to measure the diversity. It is calculated from the equation:

$$H' = -\sum_{i=1}^{S} (p_i \, ln \, p_i)$$

$$p_i = \frac{n_i}{N} \; ; \quad i = 1, 2, 3, \dots, S$$

where, S = the number of species

n_i= the number of individuals of the i^{th} species

N = the total number of individuals for all S species

p_i= the proportional abundance of the i^{th} species

2.10.3.3 Community Evenness

The homogeneity of the communities was measured by Pielou's evenness index (J'):

$$J' = \frac{H'}{H_{max}}$$

Where H_{max} is the maximum possible diversity, which would be achieved if all species were equally abundant (Clarck & Warwick, 1994; Pilou, 1966).

2.10.4 Species abundance distributions: Log series model (Rank-abundance plot)

In graphical or distributional methods, relative abundances or biomass of different species are plotted as a graph which retained more information about the distribution than single index.

The log series distribution predicts that species arrive at an unsaturated habitat at random intervals of time and then occupy the remaining niche (with one or few dominant environmental factors) (Magurran, 1988).

The general formula for log series distribution is calculated according to Fisher et al, (1943).

The log series takes the form:

$$\propto x, \quad \frac{\propto x^2}{2}, \frac{\propto x^3}{3}, \ldots \frac{\propto x^n}{n}$$

$\propto x$ being the number of species predicted to have one individual, $\propto x^2/2$ those with two and so on (Fisher et al, 1943; Magurran, 1988).

The total number of species, S, is obtained by adding all the terms in the series which reduces to the following equation

$$S = \propto [-\ln(1-x)]$$

To calculate the expected frequencies in each abundance class x is estimated from the iterative solution of;

$$\frac{S}{N} = \frac{1-x}{x[-\ln(1-x)]}$$

Where, N = the total number of individuals in the community

Two parameters, α, the log series index, and N, summarize the distribution completely, and are related by

$$N = \propto \ln\left(1 + \frac{N}{\propto}\right)$$

α is an index of diversity.

The index was obtained from the equation

$$\propto = \frac{N(1-x)}{x}$$

The octave or doubling of species abundance class was chosen for calculations.

2.10.5 Multivariate analysis

Two multivariate methods used in the present study were the ordination and clustering technique which compare communities on the basis of the identity of the component species as well as their relative importance in terms of abundance or biomass. In multivariate analysis, data matrix was required for measuring similarity or dissimilarity of species abundance and biomass between samples. Two data matrix were used in present study. One consisted of estimates of the individual number of each species found in each of study sites and other data matrix comprised the corresponding biomass estimates. The biological data consisted of rows (species) and columns samples.

2.10.5.1 Cluster analysis

Cluster analysis (CA) is a classification technique that accomplishes the sorting of similar entities or objects into groups or "Clusters" which are arrange in a hierarchical treelike structure called dendrogram. CA aims to find natural grouping of samples in such a way that samples within a group are similar to each other, generally than samples in different groups. In present study, CA was used to group entities of the benthic communities and also the species abundance into a dendrogram according to their similarities. CA was based on Bray-Curtis similarity index with the group average linkage method. No transformation or standardization was conducted on raw data.

2.10.5.2 Non-metric multidimensional scaling ordination (nMDS)

Ordination is a term used to describe a set of techniques in which samples are arranged in relation to one or more coordinate axes. It is a map of samples and distance between samples on the ordination attempts to explain the corresponding dissimilarities in community structure. Non-metric multidimensional scaling ordination (nMDS) was used to construct an ordination of the benthic groups and the community abundances in a 2-D-map that plots similar objects close to each other in the ordination space (Clark & Warwick, 1994; Legendre & Legendre, 1998). The nMDS ordination technique was based on Bray-Curtis similarity. The stress value that indicates how well that configuration represents the multidimensional similarity between the samples based on classification from Kruskal (1964);

Stress	Goodness of fit
20%	Poor
10%	Fair
5%	Good
2.5%	Excellent
0%	Perfect

2.10.5.3 Analysis of Similarities (ANOSIM)

The ANOSIM randomization test was used test differences between communities and among study sites. There were many more species (variables) than samples in the present study. If r_W is defined as the average of all rank similarities among replicates within sites, and r_B is the average of rank similarities arising from all pairs of replicates between different sites, then a suitable test statistic is;

$$R = \frac{r_B - r_W}{M/2}$$

where,

$$M = \frac{n(n-1)}{2}$$

$$n = total\ number\ of\ samples\ under\ consideration$$

R=1 only if all replicates within sites are more similar each other than any replicates from different sites

R=0 if the null hypothesis is true, so that similarities between and within sites will be the same on average

2.10.5.4 Similarity percentages (SIMPER) routine

The major species responsible for the divisions of the samples into clusters as well as those species responsible for discriminating between communities were determined using the similarity percentages (SIMPER) routine (Clarke, 1993).

2.10.6 Statistical analysis

Visitor census was analyzed using one-way ANOVA on the number of visitors per hour, treating study localities as the factor. The species area curves were constructed using EstimateS (version 8.0) package (Colwell, 2006). The distribution models were manually plotted and linear regression of the model was calculated automatically by using excel software. Univariate diversity indices and multivariate computations: Cluster analysis, multivariate non-metric multidimensional scaling ordination (nMSD), Analysis of Similarity (ANOSIM) and similarity percentages (SIMPER) were performed using the PRIMER v.6.1.2 (Plymouth routines of Multivariate Ecological Research) software (Clarke & Gorley, 2006). All the statistical comparisons were made using SPSS software (version 16). Parametric or non-parametric one-way ANOVA test were applied to the data after testing the normality. An additional Student-Newman-Keuls (S-N-K) test of multiple comparisons of mean was applied as post-hoc test. All means are herein reported ± standard deviations.

RESULTS

3.1 Oceanographic conditions in study area

Due to proximity of the three study localities, their oceanographic conditions are indistinguishable (p=0.05, one-way ANOVA for sea surface water temperature, salinity, dissolved oxygen (DO), pH and conductivity). Moreover, the homogeneity test of ANOVA (Student-Newman-Keuls test) clearly showed that mean values of above parameters were confined into a homogeneous subset. The syntheses of the conditions in the study area are given in table 2, which report the average values of the parameters analyzed in surface waters over the period Oct., 2007 to Feb., 2008.

Table 2: The average values and standard deviation of physiochemical parameters analyzed in sea surface water of study area.

Parameter	Study locality		
	Rumassala	**Galle**	**Unawatuna**
Temperature (ºC)	29.21 ± 0.30	29.07 ± 0.28	29.14 ± 0.29
Salinity (ppt)	31.79 ± 0.46	31.89 ± 0.28	31.91 ± 0.39
DO (mg/L)	8.06 ± 0.26	8.19 ± 0.40	8.24 ± 0.22
pH	8.31 ± 0.02	8.34 ± 0.06	8.32 ± 0.02
Conductivity (mS)	52.84 ± 0.41	52.72 ± 0.53	52.64 ± 0.12

3.2 Documentation of human disturbances

The activities of people in the intertidal rocky area were diverse. The observed activities categorized into trampling, handling and exploitation were direct and indirect disturbance to the existing communities. Human disturbances were indirectly measured here as number of people found in the study area. Parametric one-way ANOVA revealed that the number of visitors per hour to the beach was significantly different (p<0.001) among the three study localities. The post-hoc test indicated that all three localities differed significantly from each other. The mean number of visitors per hour was lowest in Rumassala marine sanctuary (2.2±2.1) compared to other two study localities situated on either side of the sanctuary. Mean number of people per hour was intermediate at Galle (17.6±9.62) and highest at Unawatuna (34.6±11.6), see Figure 3.

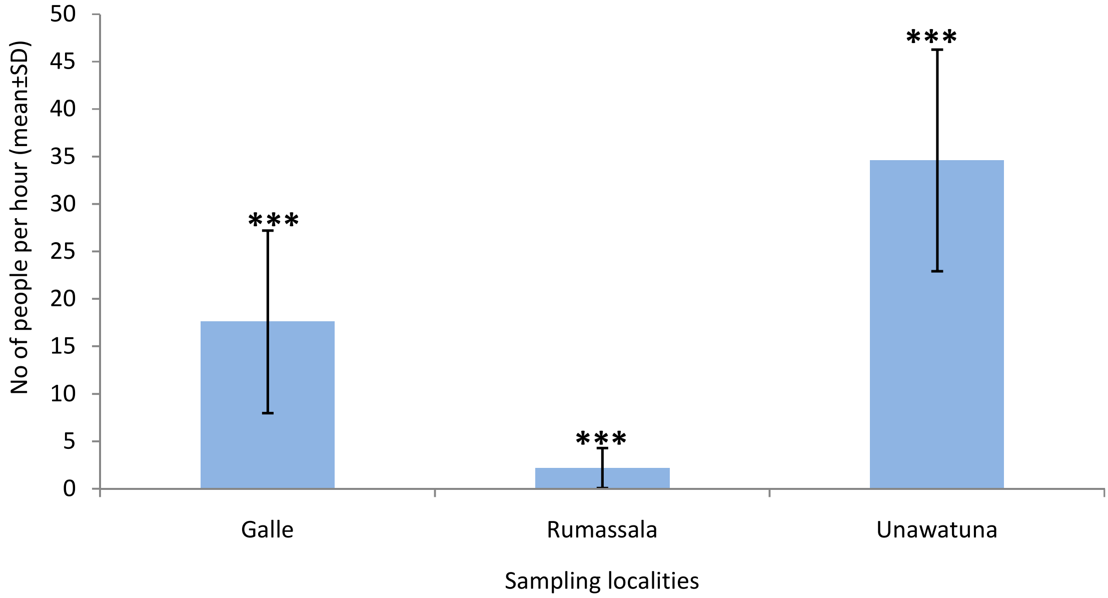

Figure 3: Mean number of people observed per hour at each sampling locality during ten instantaneous surveys over the period Sep., 2007 to Feb., 2008 (***p<0.001).

3.3 Abundance and Biomass

Species abundance differed significantly (p<0.001) between the three localities, being highest at Rumassala ($N/22.5m^2$ = 1217.50 ± 115.18), intermediate at Galle ($N/22.5m^2$= 679.65 ± 158.32) and lowest at Unawatuna ($N/22.5m^2$= 481.00±100.54). The post hoc test (S-N-K test) indicated that three localities differed significantly from each other. In details, most abundant species differed from one community to other and *Centroceras clavulatum, Cellana radiata, Littoraria scraba, Clypidina notata, Asporagopsis sp., Hypnea panosa* were the most abundant species in Rumassala. *C. radiata*, *L. scraba*, *Padina boergesenii* and *Valaniopsis pachynema* were the most abundant species in Galle, while *C. notata, C. radiata, V. pachynema* and *C. clavulatum* were more dominant in Unawatuna. In contrary, community biomass ($g/22.5m^2$) was high in Unawatuna (915.00 ± 535.10) and followed by Galle (670.33 ± 229.54) and Rumassala (403.24 ± 129.77), respectively. In species wise, Four species; *Asporagopsis sp., C. clavulatum, H. panosa and C. radiate* accounted for higher biomass in Rumassala. *V. pachynema, P. boergesenii, Acanthopora sp.,* and *C. clavulatum* were the most biomass dominants in Unawatuna, while *V. pachynema, P. boergesenii, Gelidium pussillum* and *H. panosa* were the most dominant in Galle. Abundance and biomass of the most important species in each locality are depicted in Figure 4.

Overall values of abundance and biomass for each community and those for each species are tabulated in appendix 1.

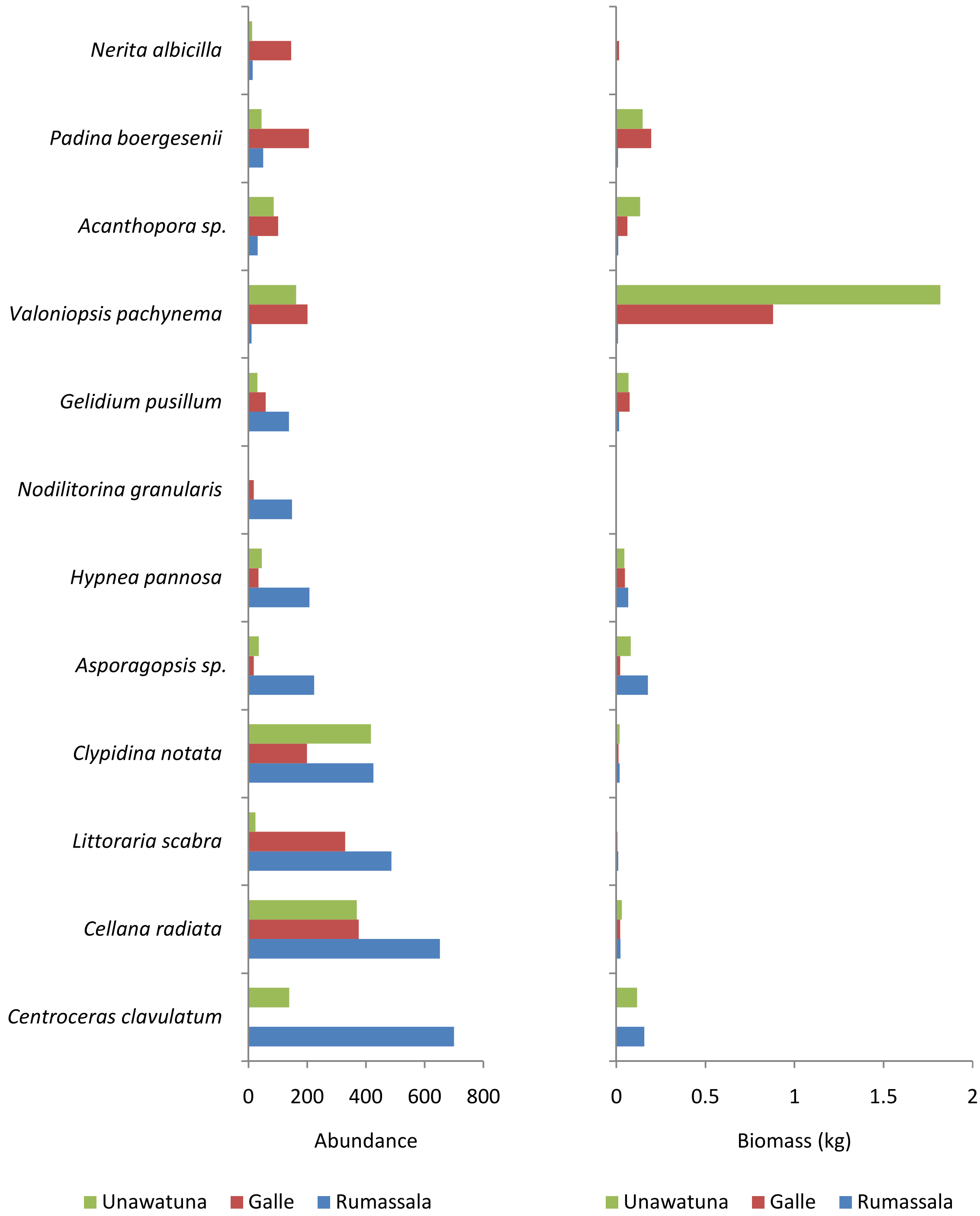

Figure 4: Abundance and biomass of the twelve most dominant species in Galle, Rumassala and Unawatuna.

3.4 Index of disturbance (Biomass to abundance ratio)

Index of disturbances for macrofauna was highest in Rumassala, intermediate in Galle and lowest in Unawatuna. The higher index value denoted the lower disturbance in Rumassala. In contrary, an index of disturbance computed for macroflora species revealed significantly higher value in Unawatuna, intermediate value in Galle and lowest value in Rumassala (Figure 5).

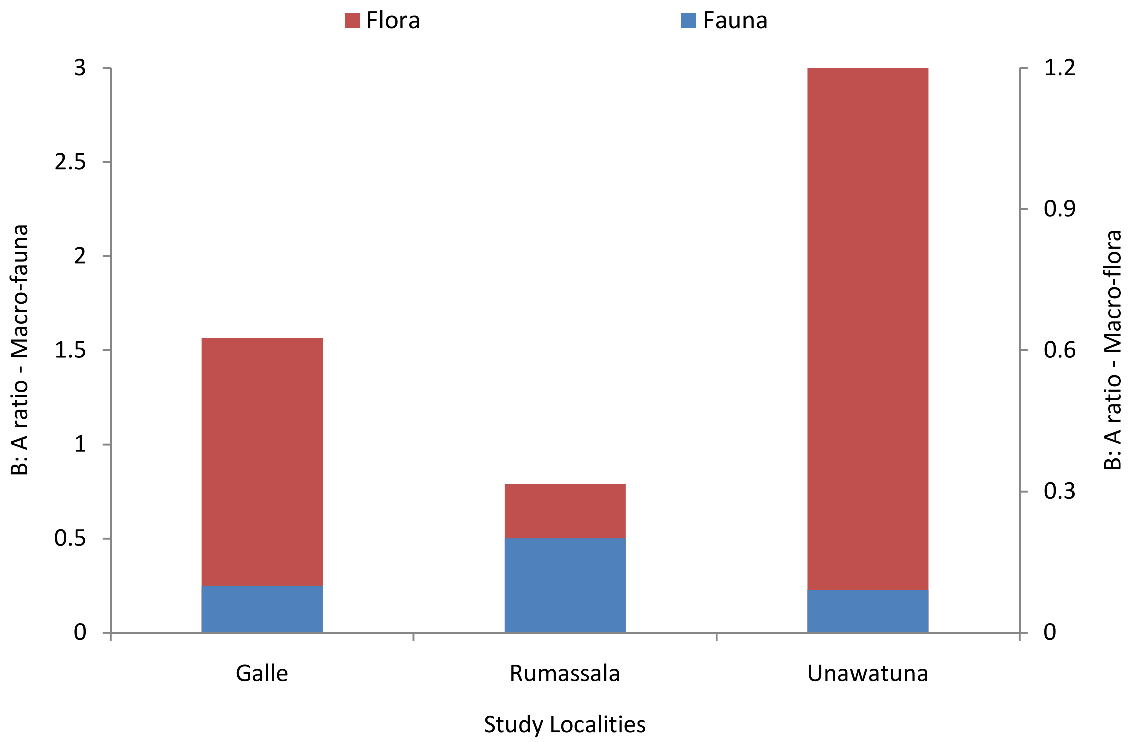

Figure 5: Index of disturbance (B: A ratio) for macro-fauna and macro-flora in three study localities (Please, refer relevant Y axis. Two vertical axis were used for better visualization of index value for macro-flora and macro-fauna)

3.5 Macrofauna to macroflora ratio

Non-parametric one-way ANOVA (Kruskal-Wallis test) indicates that macro-fauna to macro-flora ratio in terms of biomass differed significantly ($p<0.05$) between the three localities, being highest at Rumassala, intermediate at Galle and lowest in Unawatuna (Figure 6).

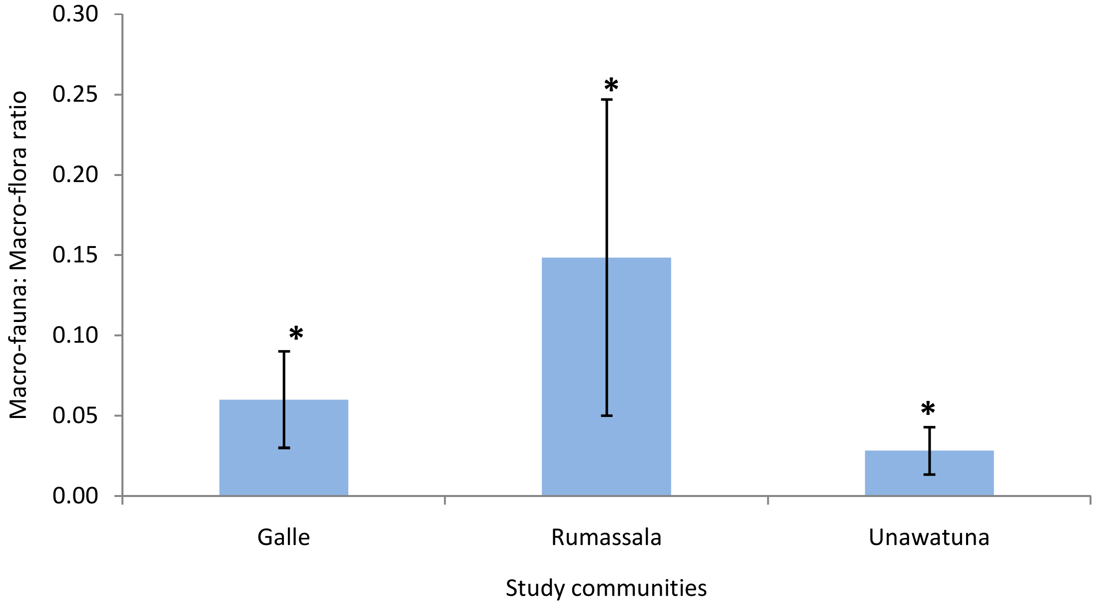

Figure 6: Macrofauna: macroflora ratio on biomass data for three study communities (*$p<0.05$)

3.6 Species richness

360 quadrat samples in total were taken during the study period at each study locality. Total area sampled at one study site during study period was 22.5m^2 and total area sampled for a study locality was 90m^2 (22.5m^2 x 4). Collectively, 96 species of macro-invertebrates and macroalgae were identified. The number of species found at the three study localities was not equal; 65% of the species were restricted to one locality, 29% occurred at two localities, and only 35% were found at all study localities. The highest numbers of species were observed at Rumassala, followed by Galle and Unawatuna. The number of species found at each study locality is summarized in Table 3. The species found from the study area and their distribution to the study localities are listed in Appendix 2.

Table 3: Number of species observed from three study localities

	Galle	Rumassala	Unawatuna
Macro-invertebrate species	31	53	25
Macroalgae species	28	28	27
Total species count	59	81	52

Species Richness indices, Margalef's index (D_{MG}), for Galle, Rumassala and Unawatuna were 7.21, 9.42 and 6.74, respectively. That is, higher species richness was observed from the community in Rumassala marine sanctuary, while the other two study communities from either side of sanctuary, Galle and Unawatuna denoted lower values, respectively.

The species rank order and their corresponding abundances at each sampling localities are depicted in figure 7. The species accumulation curves (SAC) for three communities indicates that Rumassala has the highest slope. Though SAC for Galle and Unawatuna seem to switch each other, Galle has slightly higher slope than the Unawatuna. Species rank order, in terms of the species abundance revealed that each community consisted of rare species. Existences of rare species were more prominent in the Rumassala and followed by the Galle. Cumulative species area curves for three communities indicated that the number of species was increased with cumulative sample size. This pattern was more prominent in Rumassala community and followed by the communities studied in Galle and Unawatuna. By about 150 quadrat samples (≈42% of all samples taken), the species that are representing more than 99% of the total abundance in each community have been sampled.

3.7 Community Diversity Indices

Shannon diversity index (H′), and Fishers diversity index (α) were used to compare communities in Galle, Rumassala and Unawatuna. Rumassala was the most diverse community which can be seen in higher values of H′ and α. moderately disturbed, Galle seemed to be the diverse community in comparison with Unawatuna. Computed values of Shannon index, Fishers diversity index and Piloue's Evenness, for each communities are given in table 4.

Table 4: Fisher's Diversity index, Shannon Index and Piloue's Evenness index for Galle, Rumassala and Unawatuna communities

	Galle	Rumassala	Unawatuna
Fishers Diversity index (α)	10.42	13.80	9.85
Shanon Index (H′)	3.13	3.17	2.90
Piloue's Evenness (J′)	0.77	0.72	0.73

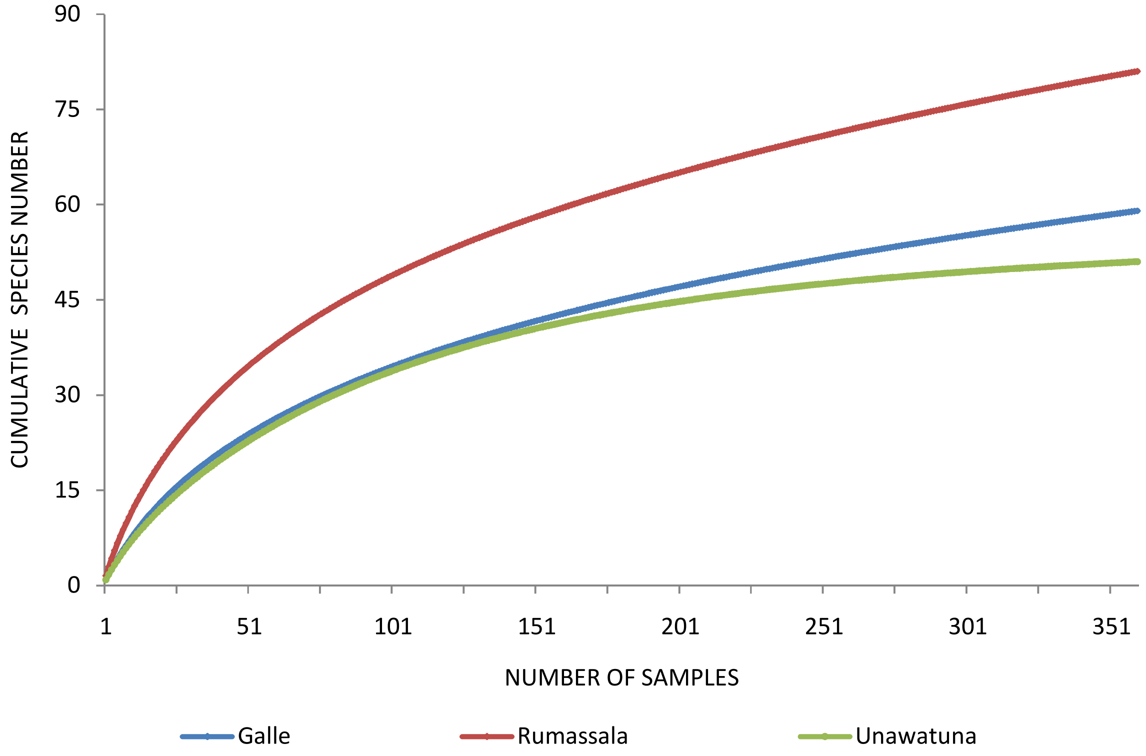

Figure 7: Randomized species accumulation curves for three communities generated using number of quadrat as a sampling effort

3.8 Log series model (rank-abundance plot)

The rank order of species observed vs. log abundance (log series model) for three communities formed three non-overlapping plots. Log abundance data against species rank order of community at Rumassala lay most right-ward side and the flatness of the line (greatest evenness) and its intersection with the x-axis (species richness) was greater in Rumassala. The plot for the Unawatuna was the most left skewed one, while that of Galle was in between them. The linear regression lines of disturbed sites had a higher slope, indicative of higher dominance and less diverse communities. The rank order of species against log abundances (log series model) and model statistics (slope and coefficient of determination) for three study communities are depicted in Figure 8.

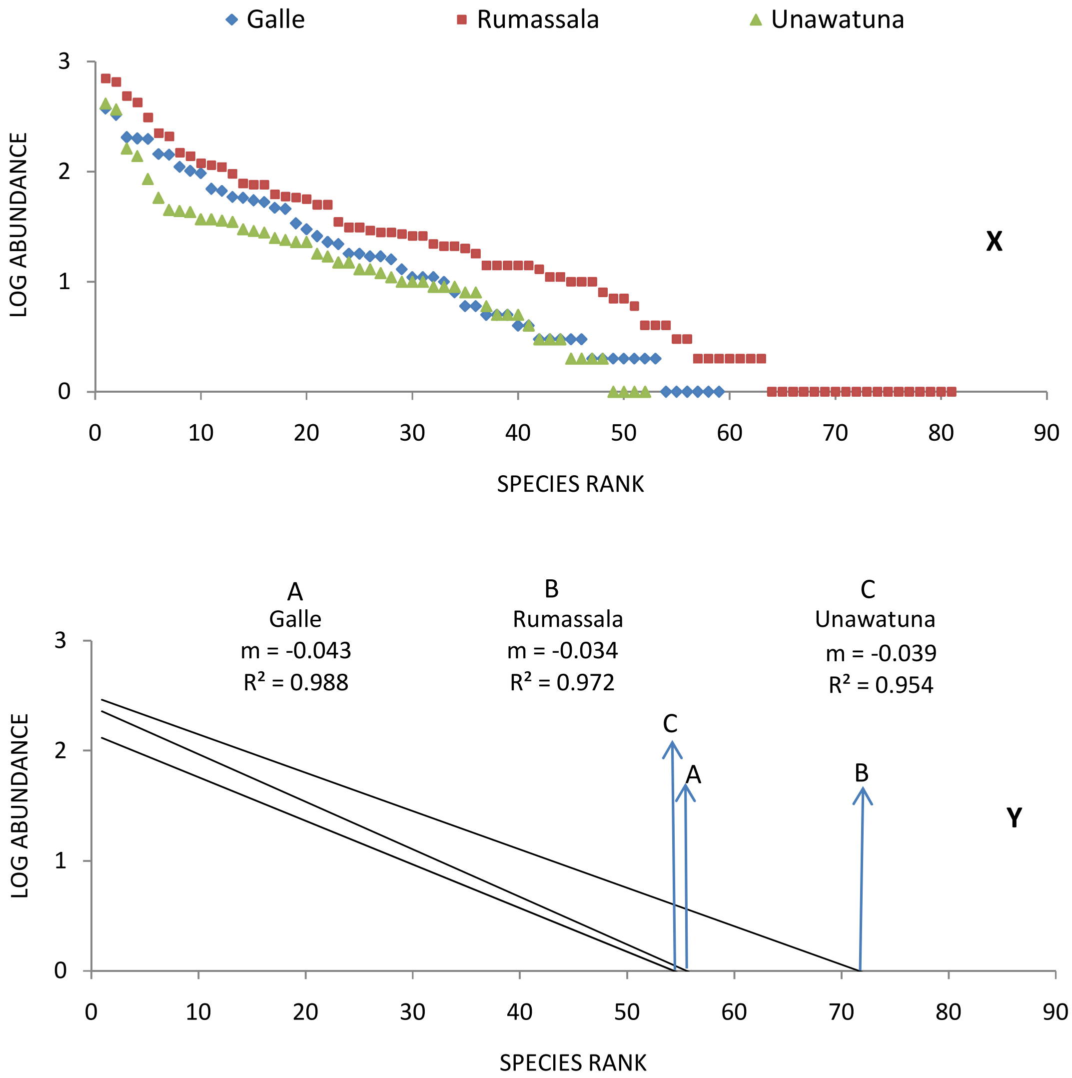

Figure 8: Rank abundance plot (log series model) (X) and linear regression analysis of community abundances (Y) (R^2 = coefficient of determination, m= slope)

3.9 Cluster analysis

The hierarchical dendrogram depicted in Figure 9 show the affinities between study sites in terms of abundance data. In dendrogram, at similarity level 37%, two major divisions are evident, cluster 1 representing sites from Rumassala sanctuary and cluster 2 comprising sites studied from either sides of sanctuary. Then, at similarity level 44%, cluster 2 split into two major groupings, designated 2a & 2b, representing the sites from Unawatuna and Galle, respectively. Resultant three groups; Rumassala, Galle and Unawatuna, were formed at similarity levels 62%, 56% and 53%, respectively. Pair-wise comparison of study sites indicates that pairs belonging to same locality had higher similarity than pairs between communities. Pair-wise similarities for each study sites are given in table 5.

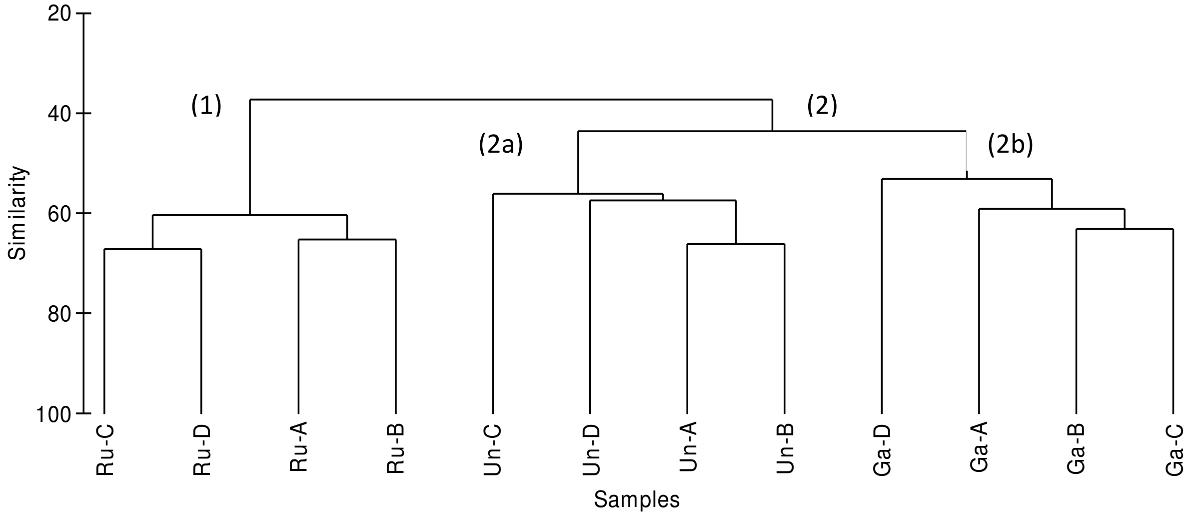

Figure 9: Hierarchical dendrogram showing group average clustering of Bray-Curtis indices of similarity based on non-transformed community abundance data at three study localities. Ru- , Ga- and Un- refer the study localities and -A, -B, -C and –D, representing sites (e.g., Ru-A = Rumassala study site A).

Table 5: Pair-wise similarity matrix for study sites (sites labels as in Figure 9)

	Ga-A	**Ga-B**	**Ga-C**	**Ga-D**	**Ru-A**	**Ru-B**	**Ru-C**	**Ru-D**	**Un-A**	**Un-B**	**Un-C**
Ga-B	59.71										
Ga-C	58.31	63.06									
Ga-D	51.32	55.52	52.37								
Ru-A	37.04	38.77	35.20	29.07							
Ru-B	43.91	41.64	43.56	34.49	65.16						
Ru-C	38.73	40.52	37.79	24.54	57.73	63.85					
Ru-D	39.25	39.87	33.12	27.30	60.40	59.30	67.10				
Un-A	40.18	44.55	40.97	41.05	45.28	47.39	34.89	35.90			
Un-B	38.85	48.78	42.46	47.57	50.94	53.22	43.16	39.11	66.06		
Un-C	41.93	43.68	47.99	47.51	35.94	41.23	28.68	30.96	54.76	59.24	
Un-D	38.52	44.16	44.10	43.96	29.46	35.26	27.41	27.26	57.67	57.05	54.11

3.10 Non-metric multi-dimensional scaling (nMDS)

Two-dimensional MDS configurations for the community abundance data showed a clear coherence of study sites within study localities which were grouped far apart from each other at the ordinal scale (Figure 10). The groupings of the study sites belonging to same locality indicated that sites within localities were more similar than those from similar locality. Stress value for this 2D separation was 0.06. At 40% similarity, Rumassala and other two localities were separated. At the 50% similarity, three communalities were completely separated at ordinal scale. The study sites in Rumassala were grouped together at 60% similarity.

3.11 Analysis of Similarities (ANOSIM)

Pair-wise comparison of one-way Analysis of Similarity (ANOSIM) test indicated significant differences between study localities (ANOSIM, Global R= 0.995, significance level of sample statistic = 0.2%). Summary of pair-wise percent significance level and R statistics for community abundance are given in Table 6.

Table 6: Summary of pair wise percent significance levels and R statistics for community abundance data as indicated by ANOSIM test (total number of permutations = 35).

Pair	**R statistics**	**Percent significance level**
Galle – Rumassala	1	2.9
Galle – Unawatuna	1	2.9
Rumassala - Unawatuna	1	2.9

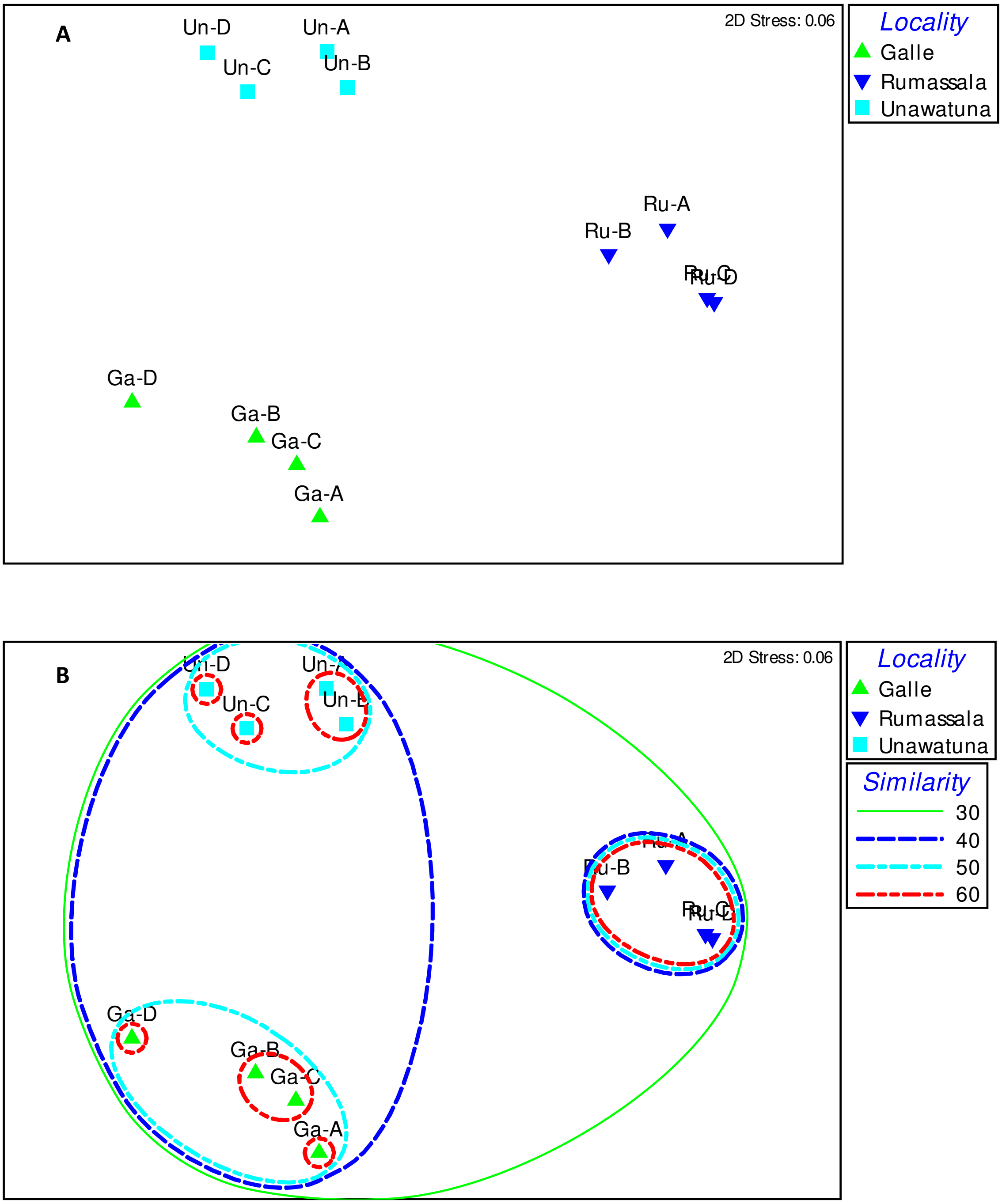

Figure 10: Two-dimensional MDS configuration for community abundance (A), with superimposed Bray-Curtis clusters (B) at the 30, 40, 50 & 60% level of comparisons between communities in Rumassala sanctuary and adjacent either side of sanctuary

3.12 Typicality of species within localities (SIMPER analysis)

Table 7 shows that average similarity within Rumassala was generally higher than that within Galle and Unawatuna. SIMPER analysis of within group similarities based on abundance data indicated that 10 species accounts for 50% of the similarity within Rumassala as compared with 9 and 5 species within Galle and Rumassala, respectively. The principal species, contributing similarity within Rumassala which do not feature prominently in Galle and Unawatuna were *Chnoospora minima*, *Nodilitorina granularis*, *Hypnea pannosa*, *Nodilitorina pyramidalis*, *Asporagopsis sp*. and *Gelidium pusilum*. The major species which featured prominently in Galle and Unawatuna but not Rumassala were *Valonipsis pachynema*, *Padina boergesenii*, *Nerita albicilla*, *Caulerpa racemosa*, *Acanthopora sp*. and *Drupa margariticola*. Of them, *Nerita albicilla*, *Caulerpa racemosa*, *Acanthopora sp*. and *Drupa margariticola* were featured only in Galle.

Table 7: Major species contributing to the average similarity within Rumassala, Galle and Unawatuna as determined by SIMPER analyses based on non-transformed abundance data and the Bray-Curtis measures of similarity

Species	Rumassala		Galle		Unawatuna	
	Av. Ab.	% con.	Av. Ab.	% con	Av. Ab.	% con
Centroceras clavulatum	175	18.77			34.75	8.99
Cellana radiata	163	18.24	94	20.27	92.25	30.1
Clypidina notata	106.25	10.54			104.25	30.51
Littoraria scabra	121.75	10.39	82.5	15.12		
Chnoospora minima	77.5	8.44				
Nodilitorina granularis	37	3.79				
Hypnea pannosa	52	3				
Nodilitorina pyramidalis	27.5	2.95				
Asporagopsis sp.	55.75	2.8				
Gelidium pusillum	34.5	2.4				
Valoniopsis pachynema			50.25	11.88	40.75	9.19
Padina boergesenii			51.5	8.58		
Nerita albicilla			36.25	6.24		

Caulerpa racemosa			24.25	4.21		
Acanthopora sp.			25.5	3.55	21.5	3.58
Drupa margariticola			13.25	3.18		
Average Similarity	**62.26**		**56.71**		**58.15**	

† The average abundances (Av.Ab.) and of these species across the sites within each locality and their individual contribution (%con.) to the average similarity within each locality are presented

SIMPER analyses based on biomass data indicate that 8 species accounted for 50% similarity within Rumassala as compared to 6 and 4 species in Galle and Unawatuna, respectively (Table 8). No species were common to three groups. The principle species contributing to similarity within Galle which did not feature prominently in Unawatuna were *Gigartina sp*., *Caulerpa racemosa*, *Dictyosphaeria versluysii* and *Acanthopora sp*. Species found in Unawatuna but not in Galle were *Centroceras clavulatum* and *Gracilaria cassa*.

Table 8: Major species contributing to the average similarity within Rumassala, Galle and Unawatuna as determined by SIMPER analyses based on non-transformed biomass data and the Bray-Curtis measures of similarity

Species	**Rumassala**		**Galle**		**Unawatuna**	
	Av. B.	**% con.**	**Av. B.**	**% con.**	**Av. B.**	**% con.**
Chaetomorpha antennina	35.56	14.73				
Centroceras clavulatum	39.45	14.59				
Sargassum cristaefolium	79.6	14.37				
Asporagopsis sp.	44.28	12.02				
Chnoospora minima	31.99	10.1				
Hypnea pannosa	16.73	7.39				
Cellana radiata	6.13	4.01				
Thais rudolphi	7.74	3.42				
Valoniopsis pachynema			220.08	50.5	454.45	62.06
Padina boergesenii			49.14	12.42	37.1	8.14
Gigartina sp.			57.53	5.97		

Caulerpa racemosa			64.15	5.97		
Dictyosphaeria versluysii			32.57	4.61		
Acanthopora sp.			15.42	3.73		
Centroceras clavulatum					29.06	6.13
Gracilaria cassa					82.26	4.63
Average Similarity	**35.53**		**39.75**		**34.43**	

† The average biomass (Av.B.) of these species across the sites within each locality and their individual contribution (%con.) to the average similarity within each locality are presented

3.13 Human disturbances vs. community Parameters

Table 9 shows the parameters analyzed for three communities with respect to the magnitude of human disturbances included in first row (disturbance as visitor censuses per hour measured by transect walk method). Community parameters computed from twelve study sites of three communities, except Index of disturbance for macroalgae, indicated that respective values are decreasing with increasing disturbances.

Table 9: Changes of community parameters with respect to the disturbance

	Locality		
Parameter	**Rumassala**	**Galle**	**Unawatuna**
Disturbance	2.2	17.6	34.6
Species richness	81	58	52
Margalef's index	9.42	7.21	6.74
Shannon Index	3.17	3.13	2.90
Fisher's index	13.80	10.42	9.85
Pielou's Evenness	0.72	0.77	0.73
Abundance	4870	2716	1929
Biomass	1613.0	2681.3	3660.0
Macro-fauna: Macro-flora ratio	0.15	0.06	0.03
Index of disturbance for fauna	0.20	0.10	0.09
Index of disturbance for flora	0.79	1.57	3.24

DISCUSSION

The present study discuss the impacts of human disturbances; trampling, handling and exploitation on rocky shore macrobenthic communities in tropical island, Sri Lanka by univariate, log series model and multivariate techniques. Outcome of the present study clearly indicate that human disturbances alter the community structure on rocky intertidal shores and observed community stress correspond to the magnitude of disturbances.

In recent years, it has become clear that humans are important forces shaping marine assemblages, both modifying the physical environment where organisms live and directly and indirectly impacting populations and assemblages (Botsford et al., 1997). Human disturbances in marine ecosystems can be assessed indirectly using communities of macrobenthic organisms (Lindegarth & Hoskin, 2001). Macrobenthic species are of special interest in this context because most of them are sessile or have limited mobility (Shin et al, 2004; Paine, 1977) and they show marked responses to environmental changes depending on their species specific sensitivity/ tolerance levels (Paiva, 2001). Disturbance are generally described as being either press-type, operate at a low level for long period or pulse-type, a discrete, usually large event and can cause either no response, have a short term impact or cause long term changes in a population (Glasby & Underwood, 1996). Many authors have investigated the impacts of human activities on rocky shore communities. Some authors (Brosnan & Cumrine, 1994) have found that chronic trampling on rocky shore reduced the abundance of barnacles and mussels, while others (Fletcher & Frid, 1996; Keough & Quinn, 1998) have observed the reduced abundance of macroalgae and indirect effect on other species. Moreover, some other authors (Povey & Keough, 1991; Fletcher & Frid, 1996) have observed the increase in bare space and shift to opportunistic species. Decline in density and diversity of algae and invertebrate have been documented by Beauchamp and Gowing (1982). In addition, effects of human exploitation on intertidal target species; changes in abundance and size of target and non-target species are well documented (Keough et al, 1993; Fernandez & Castilla, 1997). Most macro benthic studies on human disturbances are confined to either algae or fauna, separately and many studies completely rely on one taxonomic group or functional group such as mollusca and grazers. Such studies do not give the better picture on changes of community structure with respect to human disturbances on rocky shore substrata. Previous study (Pagola-Carte, 2004) to compare the perturbed community from non perturbed rocky shore macrobenthic fauna have proposed that, due to unexpected bad results, comprehensive approach for hard substrata macrobenthos which include the both macroflora and macrofauna in wide range of relative dominances are need for better results. Until now, studies on marine benthic-communities have contributed little to our understanding of links between human disturbance and changes of community structure. On the other hand, most published studies are confined to temperate regions where human disturbances to intertidal habitats are seasonal and can, therefore, have intense impact on near shore communities only during short periods of time. Such studies have shown that disturbances can alter community structure but the effects are often short lived and the system usually returns to something approximating the initial state (Sousa, 1980). For instance, Casu and others (2006) have observed the trampling effect, due to seasonal tourist visitation do not cause significant negative effect on rocky zoo-benthic community at Asinara Island, North-Western Mediterranean. Authors emphasize that an increase in the number of people and longer tourist seasons, however, can create disturbances on existing assemblages, allowing less time for recovery driving. Present work was conducted in Tropical Island where attendance by visitors is year-round, albeit with variable intensity (holiday seasons, rainy seasons). This is because of lack of seasonal variations in temperature and human pressure is higher in public holidays and weekends. Due to fact that rocky shore assemblages are subjected to a series of disturbances of variable intensity throughout the year leading to press-type disturbance. Such anthropogenic impacts on the intertidal habitats are likely to result in greater damage to the environment (Addessi, 1994). Present descriptions provide a reference to evaluate community structure on macroalgae and macro invertebrate (>5mm) with respect to human disturbances. If all macrofauna (>1mm) could be considered at least over one year period, this study would have given a much more better picture on changes of macrobenthic community structure with respect to anthropogenic disturbances.

Distribution and abundance of intertidal organisms on rocky shores are known to be influenced by a number of climatic, physical, hydrological and biological factors (Raffaelli & Hawkins, 1999). Due to proximity of study localities, physical, chemical, hydrological and climatic conditions at our study area are identical (Hettiarachchi & Samarawickrama, 2005) and it is confirmed by the observed synthesis of the conditions on physicochemical parameters of sea surface water. In fact, this could indicate that the overall environment is relatively stable due to proximity of study communities and role of physical disturbances on existing communities are similar within the study area, thus any fluctuations observed in community structure are attributed to human disturbances. Observed activities of the visitors on rocky intertidal area are diverse and could be categorized mainly into trampling, handling and exploitation. However, all biota subjected to present study but mussel, *Mytilus crassitestatus*, are not harvested for human consumption and, therefore, trampling is the major depreciative behavior of visitors on rocky intertidal assemblages in the study area, rather than collecting or picking up of some colored species by visitors. On the other hand, trampling will occur in all forms of intertidal access, though the intensity of trampling may vary with specific activities. It may reduce animal density in several ways; nevertheless the most obvious and direct effect would be the crushing impact of footsteps. Additionally, weakening attachment strength leading to increasing risk of dislodgement and structural damage to sessile organisms may increase the susceptibility to other abiotic and biotic factors such as desiccation and predation (Brosnan & Crumrine, 1994; Schiel and Taylor, 1999). As my postulated hypothesis, anthropogenic disturbances in Rumassala marine sanctuary (RMS) are very low, in terms of visitor census. Unawatuna has been subjected to heavy anthropogenic disturbances, due to its increasing importance as a popular tourist destination in southern Sri Lanka, while Galle has been subjected to low levels of disturbances, due to increasing awareness as a high security zone in the area. The documented results lead to categorize the Rumassala as undisturbed, Unawatuna as disturbed with Galle being of moderately disturbances. Comparison of these assemblages should therefore reveal marked differences in various community attributes that describe hereto from.

My original hypothesis, magnitude of human disturbance creates the proportional disturbance to intertidal habitats is well substantiated by the community abundance and biomass. One significant results of this research is, accompanying with findings of Addessi (1994), the densities of most of the macro-organisms increased with decreased human disturbances. In disturbed situations conservative species that normally dominate in non-disturbed status are often disadvantaged and it is the opportunistic species which are usually become dominants (Warwick, 1993). Present findings show the clear coherence with this common phenomenon and the most abundant species differ from one community to other. *Centroceras clavulatum* is the most abundant species in Rumassala, but *C. radiate* and *C. notate* have dominated in disturbed communities; Galle and Unawatuna, respectively. In contrary, community biomass behaves differently from the community abundance. Conservative species; *Asporagopsis sp*., *C. clavulatum*, and *H. pannosa* have accounted for community biomass at Rumassala. Though number of biomass dominant species is decreased by increasing disturbances, biomass changes due to increased disturbance are principally due to increase of opportunistic algae species, *V. pachynema* and *P. boergesenii* at Unawatuna and Galle. Results imply that disturbances have the different fundamental effect on distribution of the macrobenthic community abundance and biomass.

Arguments based on biomass and abundance is well explained by the index of disturbance which is generally more consistent in its abilities to discriminate disturbed and non-disturbed communities. Disturbance index indicate severe disturbance to the macro fauna at Unawatuna and also to a lesser degree at Rumassala. Showing the decreasing trend with increasing disturbance (Figure 5), B:A ratio for macro-fauna reflects a corresponding decrease in body size. That is, showing relatively low B:A ratio, few small bodied, opportunistic taxa apparently occur in large numbers at Unawatuna where disturbances were highest. Moreover, rapid decrease in the B:A ratio with increasing disturbances support the idea that relatively long-lived large bodied, equilibrium taxa decrease at high level of disturbances, as previously proven with same results at high level of environmental toxicants (Dauer, 1993). Present findings have clearly shown that zoo-benthic community are highly sensitive to corresponding human disturbances and disturbances can finally affect on zoo-benthic abundance and growth. Study on historical and field survey data of mainland southern California coast have shown, accompanying with present results that human activities have lead to significant and widespread decline in body size of rocky intertidal gastropod species over the last century (Roy et al, 2003). In contrary to zoo-benthos, having lower disturbance index, macroalgae at Rumassala show the higher stress (Figure 5). Perturbation or moderate perturbation verdicts in Unawatuna and Galle coincide with outstanding macro algal growth, as can be inferred from B:A ratio. Proving the argument mounted for community biomass, index of disturbance for macroalgae shows the progressive increase of opportunistic species. That is, in non-disturbed state at Rumassala, those opportunistic species are susceptibility to grazing due to high caloric contents. In such a situation late successional, slow growing forms, having low caloric value, tend to be dominants, as they are subjected to low palatability to herbivores and account for the algal biomass (Bymers et al, 2005). This indicates that undisturbed Rumassala community is subjected to top down control. In stress conditions at Galle and Unawatuna, macro-fauna including grazers are the major victims and other species previously constrained by grazing, competition etc, may actually increase in abundance. Those responses are interrelated; the reduction of biomass of grazing herbivores promotes the domination of primary space by algae. This either precludes the settlement of sessile fauna or leads to their elimination as a result of over-growth and smothering. In stress conditions, opportunistic forms of algae tend to be rapid colonizers with rapid growth rate and contributed to higher B:A ratio computed for macroflora. Therefore, it is clear that increased macrofloral community biomass is mainly, due to reduced herbivory. This positive algal response to the release from herbivory pressure has also been described for intertidal communities by many authors (Dayton, 1971; Hawkins & Hartnol, 1983). On the other hand, it can be speculated that a reduction in recruitment of many macrofaunal species due to habitat change may, in addition, provoke a bottom up regulatory force in balancing the whole community structure. However, present result is in conflict with previous studies (Addessi, 1994; Fletcher & Frid, 1996) in which authors have observed the declining response of macroalgae to the human disturbances. One possible factor that can be speculated for the contradiction with those studies is the disturbed macroalgae can grow and regenerate rapidly rather than macrofauna. On the other hand, Brosnan and Crumrine (1994) have found that foliose algae (conservative) to be susceptible to trampling but found algal tuft (opportunistic) to be much more resistant to disturbances. Separate analysis of disturbance index for macroflora and macrofauna in present study clearly show how they interact in community and how they are liable to unprecedented disturbances from visitors.

The results derived so far from abundance, biomass and index of disturbances are strongly supported by macrofauna to macroflora ratio. Having higher ratio value, Rumassala comprises the highest heterotrophic dominance and ratio has a trend to have negative relationship with increasing disturbances. Macrofauna: macroflora ratio support strong evident that opportunistic alga plays a major role in stressed communities and their role is enhanced by the magnitude of disturbances. It seems undeniable that algal assemblages are as important as fauna for the comprehensive of benthic structure and dynamics of hard substrata. These findings demonstrate the utility of comparing macrofauna and macroflora community structure in the same exercise, as this may provide useful insight into the cause of disturbances. Furthermore, while tropic interactions are the main organizing force in pelagic communities, competition for space has also to be considered in benthic communities (Schwinghamer, 1981) and such competition on hard substrata is inconceivable without algae.

Species richness and heterogeneity diversity measures have most commonly been used to assess the impact of disturbances on marine environment (Laetz, 1998; Gray, 2000). Moreno and Halffter (2000) have described the problem associated with comparing species richness among communities and used species accumulation curves (SAC) to standardize samples among sites, to predict the species richness of the sites and to estimate the minimum effort required for adequate completeness of inventories. It is explained that raw species richness counts or higher taxon counts can be rapidly compared only when taxon accumulation curves have reached or are clearly approaching, an asymptote (Gotelli et al, 2001; Moreno & Halffter, 2000). However, for invertebrate and microbial assemblages everywhere and for many taxa in tropical habitats, such asymptote may never reach even after extensive sampling (Stork, 1991; Fisher, 1999). Showing comparatively higher number of rare species, Rumassala community does not seem to approach an asymptote and moderately disturbed Galle community follows the similar trend. Though this problem encountered in present study, completeness of species inventory from study area as well as comparison of SAC and species richness in relation to human disturbance is robust here due to identical sampling scale ($90m^2$) and effort (360 quadrates) for each community. Because, Gotelli and others (2001) have emphasized that, if one or more SAC fail to reach an asymptote, the curve themselves may often be compared, after appropriate scaling. Present study records 96 macrobenthic taxa representing 38 macroalgae and 58 macro invertebrate species. So far, inventories and quantitative descriptions of macro benthic assemblages in RMS are lacking (De Vos, 2007). Present study, therefore, provides a significant contribution to our knowledge of the biodiversity of rocky macrobenthic flora and fauna at RMS, and more generally, that of Sri Lanka. It is verdict, comparing species accumulation curves on three communities that most abundant species have been encountered before completing the half of the sampling effort (180 quadrates). Opportunistic species are more prevalent and rare species are very low in

Unawatuna as inferred from abundance data (appendix 1). Also, observed numbers of taxa are too low in Unawatuna. Therefore, SAC for Unawatuna is likely to approach the asymptote first. In comparison with Unawatuna, observed numbers of taxa are higher in Galle and community shows the intermediate status between Unawatuna and Rumassala, having some conservative species, rare species and opportunistic species (appendix 1). This is visualized by the SAC on Galle and SAC overlap with that of Unawatuna at the middle (figure 7), but it does not show the approach to reach asymptote, as on Unawatuna. These observed patterns of SAC on three communities are confirmed by the species richness index. Computed index for species richness, Margalef's index, verdicts that Rumassala occupy the higher number of species compared to adjacent disturbed sites. Of two disturbed sites, moderately disturbed, Galle exhibits high species richness. Thus decrease in species richness could be explained by parallel increase of human disturbances (table 9). It can be argued that resultant community richness is mainly due to unavailability of suitable substrata. Present results are somewhat contrary to expectations based on Connell's (1978) intermediate disturbance hypothesis (IDH), as previously observed within exploited and non-exploited rocky infratidal macrofaunal assemblages in Transkei (Lasiak & Field, 1995). This hypothesis predicts that disturbance of intermediate severity and frequency should have a positive effect on species richness. There may be two reasons for the present result which are not in line with IDH. This relationship varies from community to community and depends on the competitive abilities of early and late successional species. On the other hand, the moderately disturbed community, Galle may be subjected to higher severity of disturbances than those needed to generate positive effect on species richness.

Of the heterogeneity diversity measures, Shannon index is more commonly used in ecology to discriminate the communities. If so, there are arguments that it is less informative (Gray, 2000; Magurran, 1988). In this regards, Fisher's index (α) and Shannon index (H') were used to discriminate the communities, as diversity measured by Fisher's index generally behave more predictably and consistently than by the other statistics (Taylor et al, 1976). Current study proves that human disturbance reduced the community abundance and, therefore, reduced abundance can reduce the community diversity, simply because there will be fever individuals present to be sampled after disturbances. Reductions in diversity have been cited as community response to environmental degradation (Rapport et al, 1985). Lower diversity in Unawatuna indicates higher disturbance to the habitats. Indeed, it is the locality in which the index of disturbance shows to be highly disturbed, having higher opportunistic species and lower community abundance. Many experimental and correlative studies, coinciding with present work have documented that disturbances reduced the diversity of benthic invertebrate assemblages (Vinson & Hawkins, 1998). For instance, in experimental study of northern U.S. stream assemblages, macro-invertebrate species density has significantly reduced in all disturbed treatments compared to un-manipulated controls (McCabe & Gotelli, 2000). Present correlative differences in diversity with disturbances (table 4) indicate higher structural differences between the communities than when only judged by the species richness. According to the niche-diversification hypothesis (Gage, 1996), high species diversity can be explained by the existence of the numerous discrete microhabitats in Rumassala where human depreciative behaviors are minimum. Low diversity, on the other hand, indicates that community is stressed by frequent disturbances and suitable habitats are limited. Outcome of previous study support my results; Littler (1980) investigated the distribution and abundance of rocky intertidal organisms in Southern California, comparing non-disturbed sites at Channel Island and disturbed sites in mainland. Author has observed that mainland sites had a decline in abundance of many species and a loss of many rare species, so that diversity was actually higher at the Island sites. Human disturbances, very intense on the mainland of southern California, was hypothesized to have been one of the reasons for the disappearance of numerous marine species in the rocky intertidal, species that are still represent in the less stressed habitats of the Channel islands.

According to the univariate diversity measures, Rumassala accounts for high species richness compared to Galle and Unawatuna, but slightly low in terms of Pielou’s evenness. Comparatively lower index values imply that there are a few species that are highly abundant and many that are rare in terms of abundance, as visualized in species accumulation curves. On the other hand, univariate measures depend on the species inventory which has been sampled from the community. Though the Pielou’s index behaves differently to other measures of heterogeneity diversity, community evenness can be compared using SAC (see Figure 7). Olszewski (2004) has recently shown that the initial slope of the SAC is equal to a common measure of community evenness. The higher initial slope in Rumassala indicates high community evenness. Likewise, of two disturbed communities, Galle has slightly higher initial slope, indicating high community evenness in comparison with Unawatuna.

There is an obvious logical problem involved in determining whether any measures of biological response to the disturbance is “working” or “not” (Warwick & Clarke, 1994). Because, many authors have observed that univariate diversity measures behave different ways in different situations (McGill et al, 2007). Therefore, the best way to determine the community response is to judge its performance against variety of other measures of biological response (Warwick & Clarke, 1994). As a method in between univariate and multivariate methods, species abundance distributions (SAD) is undoubtly considered as one of the most basic descriptions of an ecological community and has played and is likely to continue to play a central role in ecology (McGill et al, 2007). A stressed community can be identified through a comparison of SAD with a non stressed or equilibrium community. This has been successfully done in marine and benthic animal communities, using SAD such as log series and log normal distributions as reference (Wolff & Alarcon, 1993; Gray, 1981; Pearson et al, 1983; Hagvar, 1994). In the present work, log series model was used to discriminate the community of Galle and Unawatuna from Rumassala. Since log series model is by means always an ideal description of the population structure (Taylor et al, 1976) and it is mostly linear with a progressive increase in the number of rare species (Hughes, 1984). Log series model on Rumassala, representing reference model lies most rightward with higher slope indicating greatest evenness as inferred from SAC. The moderately and highly disturbed communities, Galle and Unawatuna, accompanying with species distribution pattern described by Gray (1981) and Pearson and others (1983), show the skewed distribution towards the left. This distribution pattern can be explaining, due to, differences in species abundances in terms of variation in recruitment and mortality rate. The typical community, in this case Rumassala, contains a few very abundant species and many rare species (Hughes, 1984). With increased disturbance from Galle to Unawatuna, dominant conservative species have been affected first and their abundance become low. Consecutively, few species (most are algae species) achieve a rapid population growth and their expanding populations repress further recruitment into community. The disturbance on the growth of sensitive species and the repression of recruitment on them means that sensitive species have a progressively smaller chance of reaching the population size necessary to generate typical plot. As results, competitively inferior opportunistic species have become most abundance species. Therefore, log series models provide the strong support on changes of community structure already discussed by biomass, abundance, index of disturbance and community diversity indices. Moreover, these clear coherent results indicate that community disturbance occur here are press-type disturbances which change the community structure with sustaining resilience. Skewed distributions to the left reasonably lower the Shannon index and reduced index value (H′) may, therefore, serve as stress indicators. It is clear that determination of a stable log series distribution may have the character of an "Indication or warning" and the very first sign of this warning seem to be that one or few species change their dominance, as cited by Hagvar (1994).

Though present findings investigated by univariate techniques are well confirmed by log series model, there may arise a contradiction that univariate diversity indices do not sensitive enough to detect subtle changes in community structure which are more evident in a multivariate analysis that produce much better representation of differences in community structure. For instance, Lasiak and Field (1995) have compared both approaches in a study of low-shore community structure, as in the present study and found that univariate measures such as species diversity, were poor discriminators of differences in community structure between shores subjected to shellfish gathering and those protected within reserves. Therefore, in order to achieve a robust conclusion, multivariate exploratory techniques were too applied here and outcome showed the similar tendency achieved through the community abundance, biomass, univariate measures and SAD in separation of three communities accordingly with magnitude of human disturbances. In addition, multivariate ordination and clustering methods preserve species specific information and will generally be rather sensitive in changing community patterns (Warwick et al, 1990). The observed decline in the community abundance and increase in the community biomass due to increasing opportunistic species from non-disturbed to disturbed communities have been confirmed by the similarity percentage (SIMPER) analysis. The species contribution to the 50% community similarity has decrease with increasing disturbances (Table 7) and those contributed to community biomass at Unawatuna and Galle are opportunistic species, such as *V. pachynema P. boergesenii* and *G. cassa* (Table 8). This implies that multivariate SIMPER method provide the species identity which is not given by univariate techniques. The discriminations of communities with respect to disturbances are further confirmed by cluster analysis (CA) and non-metric multidimensional scaling ordination plots (nMDS), separating study sites that are not belong to the respective community. Four study sites in a locality are much more similar each other and this similarity is confirmed by the similarity matrix (Table 5), having high similarity between sites that represent same community. It is clear that similarity measures are an appropriate coefficient for exploring biological community similarities (Clarke & Gorley, 2006), as the data matrix usually have same units of measures, abundance or biomass. This higher similarity within each community is visualized by the fused study sites into three different groups in hierarchical clustering dendrogram, as expected. Moreover, non-metric multidimensional scaling ordination plots visualize the trend (Figure 10), already observed in dendrogram, between sites and communities. The resultant two-dimensional ordination plots, display the clear pattern shown in cluster technique to separate the communities and visualize the sites belonging to same community close together, representing habitats that are very similar in community composition. Likewise, sites that are few apart correspond to habitats with very different community composition. Hierarchical dendrogram and MDS ordination plots prove that different community habitat does not overlap and sites of three localities occupy the completely different places in ordinal scale. According to Kruskal (1964), the stress value (0.06) corresponds to a good ordination with no real prospect of a misleading interpretation. As, stress value is the basis to estimate the adequacy of the MDS representation (Clarke & Gorley, 2006). Addition to the SIMPER analysis that gives the species identity, CA and MDS worth using to discriminate the communities and to interpret the outcome derived from abundance, biomass, univariate measures and log series model. Furthermore, the separation of three communities from clustering and ordination methods have confirmed by the one-way ANOSIM test with significantly higher (2.9%) similarity of study sites within each community (R=1). The lack of variability within community could, of course, simply reflect the similarity in habitat occurring and ecological processes operating, from site to site. The fact that communities occupy different status is visualized by the CA and MDS ordination and ANOSIM test confirm the discrimination statistically. Furthermore, SIMPER analysis indicate that major reason for these divisions are due to; (1) decrease abundance of macro-fauna, (2) increase abundance of opportunistic species, (3) decrease biomass of species normally found in non-disturbed areas and (4) increase biomass of opportunistic species, mainly algae. These indicate that results derived from univariate and SAD with respect to magnitude of human disturbances, are better explanatory by multivariate techniques. It has no argument that derived results from community response become more robust when communities are discriminated in multivariate terms.

CONCLUSION

Present study highlights issues regarding the impact of human activities on macrobenthic rocky shore communities in Sri Lanka, in general tropical rocky shore in Indian Ocean. Since tropical marine habitats are increasingly impacted by the effect of human growth and development, such studies are urgently needed to monitor, develop tools and manage near shore marine environments. Coastal macrobenthic communities in Sri Lanka are subjected to pres-type disturbances and macro benthicfloral and faunal sensitivity to such perturbations are not identical. Contributing community changes, considerable number of species represented in non-disturbed, Rumassala were absent from the disturbed localities (Galle and Unawatuna) and vice versa. Though some of the lost species are singletons species, most of the lost species are fairly common in Rumassala suggest that their absence can be related to absence of suitable habitats and/ or suppression of recruitment by growing opportunistic species released from the competition or herbivory pressure. Moreover, decline of macrobenthic tropic diversity with increasing disturbance in our data set imply that tropic functions was affected along with reduction in faunal complexecity. Those lead the observed changes of community parameters measured by univariate, log series model and multivariate methods. The SIMPER analysis confirmed that several of the major species responsible for discriminating the communities are, in fact, opportunistic species which are more abundant in Galle and Unawatuna. Present findings strongly support the growing concern that human activities impact on intertidal assemblages all over the world by changing community composition (Castilla & Duran, 1985; Keough et al, 1993; Adessi, 1994), decreasing diversity (Jenkins et al, 2001) and removing biomass (Povery & Keough, 1991) etc. Study proposes that ecological stress is the best measured by multiple methods and consistency of results among different approaches would provide the robustness necessary to judge the reliability of the conclusion. Present results are useful in devising regulations that can ameliorate negative effect of human pressure on beach flora and fauna in Sri Lanka. Habitat protection through well designed and effectively managed coastal environments, such as MPAs, are the major solution for very important ecological problems, fulfillment of which will promote preservation of the existing communities and the genetic diversity of rare and vanishing species. It is hope that the alarming situation outline in this study will make more people in all over the world aware of this vital problem the coastal community faces and will stimulate those who can do something to prevent the worst from happening.

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APPENDICES

Appendix 1: Species abundance and biomass (N-number; B-biomass g/90m^2) for three study localities. Zero values denotes that relevant species was not recorded at this study locality (species are listed alphabetically).

	Species	Taxonomic group	Galle		Rumassala		Unawatuna	
			N	B	N	B	N	B
1	*Acanthopleura sp.*	Mollusca	17	0.7	27	0.8	28	0.8
2	*Acanthopora sp.*	Rhodophyta	102	61.7	31	10.7	86	134.2
3	*Ahnjeltiopsis pygmaea*	Rhodophyta	0	0	14	2.1	23	4.3
4	*Asporagopsis sp.*	Rhodophyta	18	22.4	223	177.1	35	81.7
5	*Bulla ampulla*	Mollusca	0	0	1	0	0	0
6	*Calcinus sp.*	Crustacea	11	2.6	7	1.5	1	0.4
7	*Carpopeltis maillardii*	Rhodophyta	0	0	0	0	2	1.3
8	*Caulerpa racemosa*	Chlorophyta	97	256.6	76	36.8	18	36.7
9	*Caulerpa sertulariodes*	Chlorophyta	6	31.1	0	0	0	0
10	*Cellana radiata*	Mollusca	376	22.4	652	24.5	369	31.4
11	*Centroceras clavulatum*	Rhodophyta	0	0	700	157.8	139	116.2
12	*Cerithium clypeomorus*	Mollusca	30	2.0	0	0	0	0
13	*Cerithium morus*	Mollusca	1	0	1	0	0	0
14	*Cerithium obeliscus*	Mollusca	0	0	0	0	13	1.4
15	*Chaetomorpha antennina*	Chlorophyta	13	9.7	114	142.2	29	44.9
16	*Chaetomorpha gracilis*	Chlorophyta	0	0	0	0	11	23.2
17	*Champia parvula*	Rhodophyta	0	0	0	0	6	17.7
18	*Cheilosporum cultratum*	Rhodophyta	16	92.0	26	27.1	9	38.0
19	*Chnoospora minima*	Phaeophyta	17	3.4	310	128.0	58	92.8
20	*Clibanarius sp.*	Crustacea	23	1.1	59	4.0	15	1.4
21	*Clypidina notata*	Molluska	199	13.8	425	19.0	417	19.3
22	*Coenobita sp.*	Crustacea	5	0.8	1	0.9	1	0.8
23	*Conus taeniatus*	Molluska	0	0	1	0.1	3	0.2
24	*Dardanus sp.*	Crustacea	0	0	1	0.2	0	0
25	*Diadema sp.*	Echinodermata	2	10.5	8	6.1	3	9.1
26	*Dictyosphaeria versluysii*	Chlorophyta	55	130.3	0	0	0	0
27	*Dictyota ceylanica*	Phaeophyta	1	0.1	1	0.1	0	0
28	*Drupa (Morula) granulata*	Molluska	2	0.1	13	0.5	5	0.3
29	*Drupa (Morula) margariticola*	Molluska	53	2.0	31	1.0	3	0.3
30	*Drupa morum*	Molluska	2	0.1	1	0	0	0
31	*Drupa musiva*	Molluska	3	0.6	0	0	0	0

32	*Drupa ricinus*	Molluska	0	0	6	0.5	0	0
33	*Enteromorpha intestinalis*	Chlorophyta	0	0	58	26.9	37	37.8
34	*Euryomma platycarpa*	Rhodophyta	1	0.3	26	18.4	5	42.7
35	*Gelidiopsis variabilis*	Rhodophyta	0	0	0	0	25	19.6
36	*Gelidium pusillum*	Rhodophyta	59	74.9	138	16.1	30	69.3
37	*Gigartina sp.*	Rhodophyta	143	230.1	28	100.5	36	130.6
38	*Gracilaria cassa*	Rhodophyta	67	72.3	76	62.3	43	329.0
39	*Grapsus tenuicristatus*	Molluska	1	0.9	2	11.7	1	1.3
40	*Grateloupia lithophila*	Rhodophyta	0	0	78	7.4	0	0
41	*Halimeda opuntia*	Chlorophyta	111	258.2	0	0	15	97.7
42	*Holothuria atra*	Echinodermata	0	0	0	0	1	10.0
43	*Hypnea pannosa*	Rhodophyta	34	48.4	208	66.9	45	45.2
44	*Jania adhaerens*	Rhodophyta	11	12.0	0	0	10	17.3
45	*Jania natalensis*	Rhodophyta	2	0.2	22	44.5	0	0
46	*Latirolagena sp.*	Molluska	0	0	2	0.3	0	0
47	*Laurencia heterolada*	Rhodophyta	46	26.7	0	0	9	52.7
48	*Laurensia obtusa*	Rhodophyta	47	25.6	14	7.3	0	0
49	*Ligia sp.*	Crustacea	6	0.1	29	0.5	8	0.1
50	*Littoraria scabra*	Molluska	330	6.4	487	10.3	24	0.3
51	*Littoraria undulate*	Molluska	3	0.2	20	6.9	0	0
52	*Littorina sp.*	Molluska	5	0	10	0.1	0	0
53	*Melampus fasciatus*	Molluska	0	0	11	0.2	0	0
54	*Melampus flavus*	Molluska	0	0	62	0.9	8	0.2
55	*Monetaria annulus*	Molluska	0	0	1	0.1	0	0
56	*Monetaria moneta*	Molluska	0	0	1	0.1	0	0
57	*Mytilus crassitestatus*	Molluska	0	0	50	2.2	0	0
58	*Neries sp*	Polychaeta	11	0.4	35	1.2	9	0.8
59	*Nerita (Retena) costata*	Molluska	4	2.0	18	6.2	0	0
60	*Nerita (Retena) plicata*	Molluska	10	1.2	21	2.7	17	0.8
61	*Nerita albicilla*	Molluska	145	15.9	14	1.5	12	1.1
62	*Nerita sp.*	Molluska	0	0	4	2.6	0	0
63	*Nodilitorina granularis*	Molluska	18	0.1	148	1.1	0	0
64	*Nodilitorina pyramidalis*	Molluska	58	0.5	110	1.1	0	0
65	*Notohaliotis sieboldi*	Molluska	0	0	2	2.5	0	0
66	*Ovatipsa caurica dracaena*	Molluska	0	0	1	0	0	0
67	*Oxyperas triangularis*	Molluska	0	0	1	0	0	0
68	*Padina boergesenii*	Chlorophyta	206	196.6	50	8.9	44	148.4
69	*Patelloida saccharina lanx*	Molluska	3	0.3	2	0.1	0	0
70	*Penepatella stellaeformis*	Molluska	0	0	4	0.4	0	0

71	*Percnon sp.*	Crustacea	0	0	1	0.1	0	0
72	*Pleuroploca sp.*	Molluska	0	0	2	0	0	0
73	*Saccostrea cucullata*	Molluska	8	0.3	56	16.4	0	0
74	*Sanhaliotis planate*	Molluska	0	0	1	0.8	0	0
75	*Sarcodia montagneana*	Rhodophyta	70	32.5	21	16.8	4	14.4
76	*Sargassum cristaefolium*	Onchrophyta	26	31.6	119	318.4	23	136.2
77	*Sargassum wightii*	Onchrophyta	1	0.7	0	0	0	0
78	*Scinaia carnosa*	Rhodophyta	2	0.5	2	12.6	10	5.3
79	*Septifer bilocularis*	Molluska	0	0	1	0.2	0	0
80	*Squamopleura sp.*	Molluska	0	0	4	0.5	5	0.3
81	*Tetraclita sp.*	Crustacea	2	0.9	11	0.5	13	0.5
82	*Thais alveolata*	Molluska	0	0	1	1.9	0	0
83	*Thais rudolphi*	Molluska	3	0.6	28	31.0	2	0.3
84	*Thais tissoti*	Molluska	2	0.3	2	0.2	0	0
85	*Tripneustes sp.*	Echinodermata	4	63.7	0	0	0	0
86	*Trochus radiatus*	Molluska	3	0.4	95	11.2	0	0
87	*Trochus tentorium*	Molluska	0	0	3	1.2	0	0
88	*Ulva fasciata*	Chlorophyta	0	0	14	14.7	0	0
89	*Ulva lactuca*	Chlorophyta	1	0.1	7	5.3	37	19.9
90	*Ulva rigida*	Chlorophyta	22	1.5	10	3.5	0	0
91	*Valonia fastigiata*	Chlorophyta	5	31.2	14	15.4	0	0
92	*Valoniopsis pachynema*	Chlorophyta	201	880.3	10	9.1	163	1817.8
93	*Virroconus ebraeus*	Molluska	0	0	3	0.1	2	0.1
94	*Wrangelia argus*	Rhodophyta	0	0	1	0.1	0	0
95	*Voluta lapponica*	Molluska	0	0	1	0.3	10	3.9
96	*Zeuxis velatus*	Molluska	0	0	1	0	2	0.1
Total value (total area sampled= 90m^2)			**2720**	**2681.3**	**4870**	**1613.0**	**1924**	**3660.0**

Appendix 2: List of macroinvertebrate and macroalgae species found from the study area and their distribution to the study localities (compiled list are in alphabetical order)

	Species	Taxonomic group	Galle	Rumassala	Unawatuna
1	*Acanthopleura sp.*	Mollusca	X	X	X
2	*Acanthopora sp.*	Rhodophyta	X	X	X
3	*Ahnjeltiopsis pygmaea*	Rhodophyta		X	X
4	*Asporagopsis sp.*	Rhodophyta	X	X	X
5	*Bulla ampulla*	Mollusca		X	
6	*Calcinus sp.*	Crustacea	X	X	X
7	*Carpopeltis maillardii*	Rhodophyta			X
8	*Caulerpa racemosa*	Chlorophyta	X	X	X
9	*Caulerpa sertulariodes*	Chlorophyta	X		
10	*Cellana radiata*	Mollusca	X	X	X
11	*Centroceras clavulatum*	Rhodophyta		X	X
12	*Cerithium clypeomorus*	Mollusca	X		
13	*Cerithium morus*	Mollusca	X	X	
14	*Cerithium obeliscus*	Mollusca			X
15	*Chaetomorpha antennina*	Chlorophyta	X	X	X
16	*Chaetomorpha gracilis*	Chlorophyta			X
17	*Champia parvula*	Rhodophyta			X
18	*Cheilosporum cultratum*	Rhodophyta	X	X	X
19	*Chnoospora minima*	Phaeophyta	X	X	X
20	*Clibanarius sp.*	Crustacea	X	X	X
21	*Clypidina notata*	Molluska	X	X	X
22	*Coenobita sp.*	Crustacea	X	X	X
23	*Conus taeniatus*	Molluska		X	X
24	*Dardanus sp.*	Crustacea		X	
25	*Diadema sp.*	Echinodermata	X	X	X
26	*Dictyosphaeria versluysii*	Chlorophyta	X		
27	*Dictyota ceylanica*	Phaeophyta	X	X	
28	*Drupa (Morula) granulata*	Molluska	X	X	X
29	*Drupa (Morula) margariticola*	Molluska	X	X	X
30	*Drupa morum*	Molluska	X	X	
31	*Drupa musiva*	Molluska	X		

32	*Drupa ricinus*	Molluska		X	
33	*Enteromorpha intestinalis*	Chlorophyta		X	X
34	*Euryomma platycarpa*	Rhodophyta	X	X	X
35	*Gelidiopsis variabilis*	Rhodophyta			X
36	*Gelidium pusillum*	Rhodophyta	X	X	X
37	*Gigartina sp.*	Rhodophyta	X	X	X
38	*Gracilaria cassa*	Rhodophyta	X	X	X
39	*Grapsus tenuicristatus*	Molluska	X	X	X
40	*Grateloupia lithophila*	Rhodophyta		X	
41	*Halimeda opuntia*	Chlorophyta	X		X
42	*Holothuria atra*	Echinodermata			X
43	*Hypnea pannosa*	Rhodophyta	X	X	X
44	*Jania adhaerens*	Rhodophyta	X		X
45	*Jania natalensis*	Rhodophyta	X	X	
46	*Latirolagena sp.*	Molluska		X	
47	*Laurencia heterolada*	Rhodophyta	X		X
48	*Laurensia obtusa*	Rhodophyta	X	X	
49	*Ligia sp.*	Crustacea	X	X	X
50	*Littoraria scabra*	Molluska	X	X	X
51	*Littoraria undulate*	Molluska	X	X	
52	*Littorina sp.*	Molluska	X	X	
53	*Melampus fasciatus*	Molluska		X	
54	*Melampus flavus*	Molluska		X	X
55	*Monetaria annulus*	Molluska		X	
56	*Monetaria moneta*	Molluska		X	
57	*Mytilus crassitestatus*	Molluska		X	
58	*Neries sp*	Polychaeta	X	X	X
59	*Nerita (Retena) costata*	Molluska	X	X	
60	*Nerita (Retena) plicata*	Molluska	X	X	X
61	*Nerita albicilla*	Molluska	X	X	X
62	*Nerita sp.*	Molluska		X	
63	*Nodilitorina granularis*	Molluska	X	X	
64	*Nodilitorina pyramidalis*	Molluska	X	X	
65	*Notohaliotis sieboldi*	Molluska		X	
66	*Ovatipsa caurica dracaena*	Molluska		X	

67	*Oxyperas triangularis*	Molluska		X	
68	*Padina boergesenii*	Chlorophyta	X	X	X
69	*Patelloida saccharina lanx*	Molluska	X	X	
70	*Penepatella stellaeformis*	Molluska		X	
71	*Percnon sp.*	Crustacea		X	
72	*Pleuroploca sp.*	Molluska		X	
73	*Saccostrea cucullata*	Molluska	X	X	
74	*Sanhaliotis planate*	Molluska		X	
75	*Sarcodia montagneana*	Rhodophyta	X	X	X
76	*Sargassum cristaefolium*	Onchrophyta	X	X	X
77	*Sargassum wightii*	Onchrophyta	X		
78	*Scinaia carnosa*	Rhodophyta	X	X	X
79	*Septifer bilocularis*	Molluska		X	
80	*Squamopleura sp.*	Molluska		X	X
81	*Tetraclita sp.*	Crustacea	X	X	X
82	*Thais alveolata*	Molluska		X	
83	*Thais rudolphi*	Molluska	X	X	X
84	*Thais tissoti*	Molluska	X	X	
85	*Tripneustes sp.*	Echinodermata	X		
86	*Trochus radiatus*	Molluska	X	X	
87	*Trochus tentorium*	Molluska		X	
88	*Ulva fasciata*	Chlorophyta		X	
89	*Ulva lactuca*	Chlorophyta	X	X	X
90	*Ulva rigida*	Chlorophyta	X	X	
91	*Valonia fastigiata*	Chlorophyta	X	X	
92	*Valoniopsis pachynema*	Chlorophyta	X	X	X
93	*Virroconus ebraeus*	Molluska		X	X
94	*Wrangelia argus*	Rhodophyta		X	
95	*Voluta lapponica*	Molluska		X	X
96	*Zeuxis velatus*	Molluska		X	X